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Errata.—On page 225 and 226, for *fig.* 1, read *fig.* 4.

THE
EMPORIUM
OF
ARTS AND SCIENCES.

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Of COPPER *and the Manufactures dependant on Copper.*

Under this head I shall treat briefly

Of the ores of copper.
Of the assay, and analysis of copper ores.
Of the reduction or smelting of copper ores.
Of the refining of black copper.
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Of the ores of Copper. Copper is found native: it is also found mineralized, by oxygen, by sulphur, by arsenic, by both sulphur and arsenic, by the carbonic acid, by the sulphuric acid, by the muriatic acid, by the phosphoric acid, by the arsenic acid. It is found in the state of an ore, frequently containing iron, some times silver, some times zinc, some times antimony, some times lead; one or more of these.

Copper is found native, on the immediate vicinity of some part of Lake Superior, of which I have seen specimens, but cannot point out the place.. I have also specimens of native copper from a mine in Maryland.

The common sulphuret of copper, is found in Connecticut, in Maryland, in New Jersey, in some parts of Pennsylvania, in Virginia; but I know of no place where it is worked to profit.

The oxyds, are *red oxyd*, containing 88,5 copper, 11,5 oxygen. *Azure* or mountain blue 70 copper, 20 carbonic acid, 10 oxygen. *Malachite*, mountain green, 58 copper, 18 oxygen, 12,5 carbonic acid, 11,5 water. *Sulphuretted* copper ores: these vary greatly in the quantity of copper they contain. *Arseniated* copper ore, such as the green micaceous, the olive-green foliated, the brownish-green fibrous—these contain from 49 to 60 of copper, combined with arsenic acid. *Phosphat* of copper, greyish-black on the outside, green internally containing 68,13 of copper in the state of oxyd, and 30,95 of arsenic. *Muriat* of copper hitherto found only in Peru

and Chili. *Grey* copper ore, usually containing antimony, lead, iron and silver: poor in copper. *Brown earthy coloured* copper ores containing much iron.

The sulphurets and arsenicated ores, are those which are usually smelted for the purposes of manufacture, almost all of which contain iron also in various proportions. The copper ore at Mr. Coleman's Cornwall Furnace, contains so much iron, as to be of little value, either as copper or iron ore.

Of the assay, and analysis of copper ores. By an *assay* of an ore, is meant the process used to ascertain the quantity of metal contained in it: by the *analysis* of an ore, is meant the process used to ascertain all its component parts.

The assay of copper ores, (though by no means so accurate a method of ascertaining their metallic contents as a regular analysis) being the method by which the market price of the ore is always determined, requires the first notice. The best method, upon the whole, of conducting it, is as follows.

First, expose a small piece of the ore, under examination to the action of the blow-pipe, and by the appearance and odour of the vapour given out, it is easy to discover whether it contains any arsenic or sulphur. It may very probably contain both, in which case take 300 grains of the ore coarsely pulverized, mix it with half its weight of saw-dust, and keep it at a moderate red heat in an earthen crucible, till the disengagement of arsenical vapour entirely ceases. Then pour the contents of the crucible into an iron mortar, and reduce them carefully to a fine powder. Transfer this powder to a test, a tile or piece of earthen ware that will stand the fire and expose it to a good red heat, with occasional stirring, till both the charcoal and the sulphur are burnt off. The residue is then to be accurately mixed with one twelfth of its weight of lamp-black, half its weight of clear white sand, one fourth of its weight of dry pearl ash, and its weight of *pulverized*

glass of borax, with a drop or two of oil; the mass thus formed, is to be put into a sound earthen crucible, a cover is to be luted on, and the whole is to be placed in a good wind furnace. The heat should be moderate for the first quarter of an hour, to allow the borax time to combine with the earthy impurities of the ore; then a moderate white heat is to be applied for about twenty minutes. After this, the crucible being withdrawn and cooled, is to be carefully broken, and will be found to contain a button of copper, covered by vitreous scoriæ. The purity of the copper thus procured, is to be estimated from its colour, softness, malleability, and tenacity; after which, a part of it may be cupelled with pure lead, in order to ascertain whether it holds any silver or gold. If the ore contains sulphur, but no arsenic, it may be mixed with half its weight of charcoal, and roasted on a test, without being previously heated in the crucible. If the ore contains neither sulphur nor arsenic, it should be first moderately ignited in a covered crucible, to drive off any moisture, and may then be treated with sand, alkali, borax and lamp black, as already described.

The proper analysis, by means of liquid menstrua, is however much more accurate than even the most carefully conducted assay, and the general mode of proceeding with the ores of copper is, upon the whole, very simple. The copper, together with the other metals with which it may happen to be mixed, is to be separated from the silex and sulphur, by means of an acid, the other metals are then to be got rid of by their appropriate reagents, and the copper is then to be procured either in the state of green carbonat, of black oxyd, or of pure metal; of the first, 180 parts are equivalent to 100 of metallic copper; and of the second, 100 parts contain 80 of metal.

Previously to undertaking an analysis, a part of the specimen, under examination, should be subjected to the usual reagents, in order to ascertain, not indeed the pro-

portion, but the nature of the ingredients of which it consists; and, in few cases is this more necessary than in the analysis of the ores of copper, both as they are so numerous and so various in their composition. This previous examination being duly performed, the analysis may be conducted in the following manner:

For the analysis of the *pyritical*, and other *sulphurized ores of copper*, provided they contain neither silver nor lead, take 200 grains of the pulverized ore, and digest it at a boiling heat with muriatic acid, (adding occasionally a few drops of nitric acid) till every thing soluble in this menstruum is taken up. Of the insoluble portion, a part, consisting chiefly of sulphur, will be found floating on the liquor; and this being washed, dried, and weighed, is to be ignited on a test, by which the sulphur will be burnt off, and its amount may be estimated from the loss of weight sustained by the process. The incombustible residue is to be digested in a little warm muriatic acid, and what remains insoluble, is to be added to the other insoluble residue. The muriatic solutions being mixed together, the whole is to be decomposed by carbonated potash, and the precipitate, hence resulting, is to be digested in repeated portions of caustic ammonia, as long as this latter acquires any blue tinge. The whole of the copper, and nothing else, will thus be taken up by the ammonia, from which it may be obtained in the state of black oxyd, by the addition of a little caustic potash, and a boiling heat. The residue, insoluble in ammonia, consists of oxyd of iron, with perhaps a little alumine, which may be separated by caustic potash, the alumine alone being soluble in this fluid. Finally, the portion insoluble in muriatic acid, may be considered as little else than silex.

The ores which, besides *copper*, *sulphur*, and *iron*, contain *silver*, *lead*, and *antimony*, may be thus analyzed. The ore, reduced to fine powder, is to be repeatedly di-

gested with moderately diluted nitric acid, as long as any thing continues to be taken up by this menstruum. To the nitric solution is then to be added muriat of soda, which will throw down the silver in the state of luna cornea; this being separated, the lead is to be precipitated in the form of sulphat, by sulphat of soda; the solution is now to be supersaturated with ammonia, which will dissolve the copper, and leave behind the oxyd of iron, with probably a little alumine and silex. The copper is to be procured from the ammoniacal solution, in the manner directed in the preceding paragraph; and the oxyd of iron may be separated from the admixed earths, by caustic potash. That portion of ore, insoluble in nitric acid, is to be digested in muriatic acid, which will take up every thing except the sulphur, silex, and probably a little luna cornea. Of this insoluble residue, the sulphur is to be burnt off by gentle ignition, and the remainder is to be fused with twice its weight of pearl ash, by which the silver in the luna cornea will be reduced to the metallic state. The muriatic solution being concentrated by evaporation, and then poured into a considerable quantity of water, will deposit the antimony in the form of a white oxyd.

The simple *oxyds of copper*, are best analyzed by digestion in nitric acid, and then supersaturating the solution with ammonia, by which any casual admixture of iron will be separated.

The *carbonats of copper* are to be thus treated. One portion is to be gently calcined in a covered crucible, and the loss of weight sustained, indicates the united amount of the water and carbonic acid. A second portion is to be thrown into a known quantity of dilute sulphuric acid, and the loss of weight, by the effervescence which ensues, shows the amount of carbonic acid. The sulphat of copper thus obtained, may be subsequently decomposed, either by a stick of zinc, or by liquid ammonia.

The *arseniats of copper* are most conveniently ana-

lyzed by first moderately heating them, in order to drive off and thus estimate the water, and then digesting the residue in dilute nitric acid, by which it will be entirely dissolved; nitrat of lead is then to be dropped in as long as it occasions any precipitate, and this latter being removed, the fluid is to be evaporated nearly to dryness, after which, warm alcohol is to be added, which will take up the whole, except a white powder; this powder, and the precipitate on the addition of nitrated lead, are arseniat of lead, 33,66 *per cent.* of which is arsenic acid. The alcoholic solution is then to be evaporated nearly to dryness, and then to be digested with ammonia, which will take up the copper, leaving behind any oxyd of iron that may have happened to be contained in the ore. The ammoniuret of copper, being decomposed by caustic potash, gives the copper in the state of black oxyd, which is that in which it exists in the ore.

The analysis of *muriat of copper* is very simple. It was thus effected by Klaproth. The ore, being pulverized, was dissolved in cold nitric acid, with the exception of 1,5 *per cent.* of oxyd of iron; the solution being then diluted, nitrat of silver was added, till it occasioned no further precipitate; the luna cornea thus obtained indicated, according to the known proportions of this salt, the amount of muriatic acid in the ore. The nitrous solution was then decomposed, and the copper obtained in the metallic form, by means of a bar of iron.

Phosphat of copper was thus analyzed by Klaproth. On digestion in nitric acid, the whole was taken up except a few grains of quartz; the excess of acid in the solution was then saturated by potash, and acetite of lead was poured in till it had quite ceased to occasion any precipitate; the phosphat of lead, thus obtained, was separated from the solution, and sulphat of soda was added to decompose and precipitate the small excess of acetite of lead which had been made use of. A little sulphuric acid

was then added to the solution, and the copper was precipitated in the usual way, by means of a bar of iron.

Analysis of Copper Ores.

The number of the analysis made of the different species of copper ores is so immense, that a selection only of the most approved can here be given; and a few general rules may be premised, which will simplify the subject.

The analysis of ores is usually conducted in one of two distinct ways, the *dry* and the *moist*, each of which has its peculiar advantages and defects.

In the dry way, the ores when they contain sulphur or arsenic (which is the case with the greater number) are first *roasted* in order to dissipate the greater part of these mineralizing substances. For this purpose, in analysis in the small way, they are mixed with about their bulk of charcoal powder (or better with fine saw-dust) and exposed to a low red heat on a flat tile or muffle, or any other convenient apparatus on which they can be thinly spread. The sulphur or arsenic soon begins to rise in fumes which should be hastened by frequent stirring, keeping the heat just below the point at which the ore would run and clot together, to prevent which is one considerable use of the charcoal or saw-dust.

When no more fumes sensibly arise, and the charcoal is entirely burnt off, the part of the ore that remains now consists of the metallic portion in the state of an oxyd, still mixed however with a quantity of sulphur or arsenic, which mere roasting will not separate, and of all the earthy matrix that may have been originally contained.

The ore is then fitted for the second process, which is that of *reduction* of the metallic oxyds to the reguline state. All that is essentially necessary to reduction is, to expose the oxyd to a high heat in contact with charcoal or carbonaceous matter of any kind, and secluded from the contact of air. In reducing the metals volatile in heat, such

as zinc or antimony, this reduction requires somewhat of a different apparatus from the fixed metals, to which chiefly the present observations apply. It has been a constant custom with chemists in almost all cases (till of late years) to add to the ore in reduction, not only a due quantity of carbonaceous matter, but also to mix it with a large proportion (seldom less than thrice its weight) of some alkaline or easily vitrifiable matter to serve as a *flux* to promote the fusion of all the heterogeneous contents of the ore, and to afford a thin flowing medium, through which the globules of reduced metal can readily fall by their superior gravity, and at last be collected in a single mass or button at the bottom of the crucible.

In all the common processes of reduction, therefore, which are usually given, the additions to the ore are of two kinds, the purpose of which should be well distinguished, namely, the carbonaceous matter, which is essential to the disoxygenation of the metallic oxyd, and the saline or fusible flux, the use of which is often highly convenient and even necessary, but also often needless or even detrimental. The invariable fault of saline fluxes as generally applied, is, that they always dissolve a portion of the metallic oxyd before it has time to pass to the metallic state, and retain it permanently, thus robbing the metallic button of a part of what otherwise would unite with it: and hence it almost invariably happens that common assays made in the dry way with saline fluxes return a less proportion of metal than the ore really contains. Nor is this loss trifling in many instances, since the accurate Klaproth found a difference of 9 per cent. between the yield of copper from a certain ore assayed in the dry way, and the same ore treated in a different manner, in the moist way. As a proof of the solution of a part of the metallic oxyd in the saline flux, it may be added that the scoria, or flux after melting, is always found deeply coloured with that precise tint which would be

given, as in the common preparation of coloured glasses, by the designed admixture of the oxyd of the metal used. Thus the scoriæ of reduced cobalt ore are of a deep blue; of fine copper, green or brown according to circumstances; of iron grass-green, and the like. The loss of metal is still greater when the ore retains a portion of sulphur, which last uniting with the alkali, acts with still more power on the metallic oxyds.

As naked alkaline fluxes are peculiarly liable to this inconvenience, some eminent docimastic chemists employ with considerable success fluxes of equal power, but with less disposition to dissolve the metallic oxyds. Of this kind are very fusible glasses made of much alkali and silex without litharge or other metallic admixture, fluor spar, lime, and above all, borax. This last produces a thinner fusion of vitrifying mixtures than an equal quantity of any other substance whatever, and hence a smaller dose of this than of the naked alkalies, will answer all the purposes of a flux, and of course the loss by solution of the metallic oxyd is much less.

A reduction of the sulphuretted ores is sometimes conveniently effected by a single operation which gives a button of metal of considerable purity. The roasting, which is always a tedious operation, is saved by mixing the ore with two or three times its weight of nitre, and projecting it into a hot crucible. The mixture dephlagrates on reaching the crucible, the sulphur is burnt and converted to sulphuric acid which unites with the potash of the decomposed nitre, and the metal, now freed from the sulphur, becomes fully oxygenated by the nitric acid and ready for reduction. This is effected by throwing in a reducing flux of tartar and pitch or any similar matter, and applying a strong heat for the requisite time.

It appears, however, that though nitre is often a good and expeditious method of freeing ores from their sul-

phur, it is better not to perform the whole reduction in a single operation, but first to separate the metallic oxyd after dephlagration (which may be done by washing) and then to reduce it by a proper flux.

The reduction of the pure oxyds or carbonated oxyds of copper, whether natural or artificial, is effected without loss, and is by far the best method, simply by heating intensely in contact with charcoal in a covered crucible.—This is in fact a very close imitation of the method of reduction in the large way of the roasted copper ores, only as these latter still contain sulphur, arsenic, iron, and other foreign matters, the process requires to be repeated many times before the copper is in a pure malleable state, in each of which, the impurities separate in the form of a thick pasty scum, as already described, under the article of reduction in the large way.

In small experiments, where saline fluxes are used, these impurities dissolve in the flux (which is one of the great uses of these substances) and one or at most two operations, will suffice.

When copper is pure (that is, of a saleable purity, for it is very rarely found absolutely pure) it is soft, malleable, and of a beautiful brilliant yellow-red where recently cut or filed. On the contrary, when containing sulphur, arsenic, or iron, it is black, dense, sonorous, brittle, and more of a vitreous than a truly metallic appearance. In this state it is called *copper-matt* or *black copper* by metallurgists. Subsequent melting in contact with air, or with fluxes, removes these impurities, and if the operation be judiciously performed, the loss sustained by the matt, in being converted into pure copper is principally that of the impurities; for it is a valuable property of this metal to be much less easily oxidated, scorified, and dissolved by sulphurets, than any of the metals with which it is usually found mixed, and particularly than iron.

After all, however, the analysis of copper ores in the dry

way can only give an approximation to accuracy in the result, except in the treatment of the pure native oxyds or carbonats, which are indeed among the most valuable ores, but are those which the seldomest come under the notice of the practical metallurgist.

The analysis of copper ores in the moist way is performed in a tolerably uniform manner, the ore being first treated with an acid which dissolves all the metallic part, leaving the sulphur and silex; after which the different metals are separately precipitated from the solution, either in the metallic state, or in certain known forms of combination, from which the metallic portion can be accurately inferred.

The particular steps of many of these analysis will be presently given; the general mode of separating copper from the metals with which it is alloyed is as follows: *from silver*, by adding to the nitrous solution of the mixed metals muriat of soda, which separates the silver, as luna cornea, and leaves the copper: *from lead*, by adding to the solution sulphat of soda, which precipitates an insoluble sulphat of lead, and leaves the copper:—*from antimony*, by digesting the mixed oxyds of copper and antimony with nitric acid, which dissolves the copper and leaves the antimony:—*from iron*, by supersaturating the mixed solution with ammonia, which redissolves the copper and leaves the oxyd of iron: or else by immersing a piece of polished iron in the solution, which will separate the copper and leave the iron in solution, (a precaution to be observed here, however, will be presently mentioned):—*from tin*, by immersing a piece of metallic tin in the solution, which will precipitate the copper only:—*from arsenic*, by dissolving in nitrous acid and adding acetite or nitrat of lead which will separate the arsenic in the form of an insoluble arseniat of lead, and leave the copper. If an excess of lead remain, add sulphat of soda, as above mentioned:—*from Nickel* in the following way;

when this metal is found it is generally in conjunction with iron; and ammonia, which precipitates all the three metals from their acid solution, redissolves, when in excess, both the nickel and copper; but to obtain the copper singly, again supersaturate with muriatic acid, and immerse a piece of iron, which will separate the copper, and leave the nickel dissolved.

Copper is obtained separate, in wet analysis, in three states, in each of which the weight may be taken, either in the metallic state, or as the green carbonat, or as the black oxyd. If a piece of polished iron is immersed in an acid solution of copper it is almost instantly covered with a brilliant coating of metallic copper, owing to an exchange having taken place, a portion of the iron being dissolved, and separating an equivalent quantity of copper from the solution. As this proceeds, the precipitate of metallic copper increases, and incrusts the remaining iron, forming a bundle of ragged filaments which the slightest force will detach if the solution is sufficiently diluted. At last the solution contains only iron, and the whole of the copper is thus obtained in the metallic state, which only requires washing and drying. This precipitation is much assisted by boiling for a short time, especially at last, without which indeed the last portions of copper will hardly separate. The solution when purely cupreous is of a fine azure blue, but when converted to a solution of iron becomes green. It should be remembered, however, that for a perfect separation of copper from iron by this method, the solution should be in the sulphuric or muriatic acids and not the nitrous, for though iron will equally displace copper from the nitrous as from the other acids, the nitrat of iron is itself largely decomposed by mere heat or exposure to air, and lets fall a fully oxidated iron, which in this case mixes with the fine filaments of the reduced copper, and vitiates the result of the analysis. When, therefore, it has been neces-

sary to employ this acid in the previous part of the analysis, the metallic contents should either be first precipitated by an alkali and redissolved in muriatic acid, or the nitric solution should be evaporated to dryness, redissolved in muriatic acid, and again dried and moderately heated for some time, whereby the nitrous acid is expelled, and a metallic muriat remains for further treatment.

Instead of iron, tin or especially zinc may be used as the precipitant of the copper from its solution: these act more speedily and with equal certainty. With either of these two, as their muriat is colourless, the total absence of the copper (provided iron or nickel is not at the same time present) is seen by the solution becoming entirely void of colour.

Mr. Chenevix has also remarked * a singular circumstance in these precipitations, which is, that if the acid, (particularly the muriatic) be in excess, a quantity of hydrogen is disengaged, as occurs in the common solutions of these metals, and the whole of the copper is separated in a very short time. With muriat of copper, zinc, and an excess of muriatic acid, the separation is surprisingly rapid, and much advantage may be made of this fact in the analysis of copper ores.

It is to be observed, however, that zinc will precipitate iron as well as copper from its solutions, but scarcely any of the iron will separate till all the copper is precipitated. Thus if zinc is added to a mixed solution of sulphat or muriat of iron and copper, the first precipitate is obviously copper and little else, but at the time when the solution begins scarcely to turn blue with ammonia, a black powdery oxyd of iron mixes with the copper. Even if no iron be contained in the cupreous solution, if there is an excess of acid, and *common* zinc (which always contains iron) be used, some of it will still appear in the precipitate; the excess of acid appearing first to dissolve

*Phil. Trans. for 1801, p. 211.

both the zinc and iron, and the latter being again separated by the zinc that remains. On this account, perhaps, iron is a more accurate reagent than zinc in these analysis. As the muriat of copper seems to yield its metal with more ease than the sulphat, it might perhaps be of use previously to convert the sulphat into a muriat by the addition of common salt. The colour immediately changes to green, which is a proof of this change of the cupreous salt.

The report of the assay will probably be still more accurate, if the precipitated copper, after being washed and dried, instead of being immediately weighed, is put into a small crucible, moistened with a drop or two of oil, covered with borax, and strongly heated for a few minutes whereby it becomes a solid button of good malleable copper.

The second state is that of the green carbonat. If carbonated potash or soda be added to a solution of copper, a green precipitate is formed, which, when washed and dried at the heat of boiling water, gives an uniform green powder. Its exact nature will be mentioned when describing the carbonat of copper, but it may be here added, that 180 parts of this carbonat are equivalent to 100 of metallic copper, and may be reckoned as such in all analysis. But as the pure fixed alkalies give a precipitate which may occasionally be confounded with this carbonat, this method of estimation is not quite so good as the following.

The third state in which copper may be estimated is that of black oxyd. If the green carbonat last mentioned (and it need not be washed with particular care nor dried) be boiled for a few moments in caustic potash, it at once shrinks considerably and becomes a deep brownish black fine powder, which is a pure oxyd of copper in its highest state of oxygenation. One hundred parts of this oxyd, well washed and dried in a low red heat for a

minute or two, invariably contain eighty parts of pure metallic copper. The ammoniated copper gives the same oxyd when boiled with potash.

It is also produced at once by adding potash or soda to the acid solutions of copper, and *boiling for a minute or two* (which last is an essential circumstance) and this is a better method of proceeding in analysis, since an excess of carbonated alkali will redissolve a part of the green carbonat, and vitiate the analysis, whereas no such effect is to be feared from an excess of the pure fixed alkalies at a boiling heat.

The leading steps of the actual analysis of some of the principal copper ores by the most accurate chemists may now be given in a few words, as a specimen of the mode of proceeding in different cases.

Of the ores composed chiefly of Copper, Iron, and Sulphur.

The vitreous copper ore was thus analysed by Klaproth.*

To 200 grains of the powdered ore muriatic acid was added in a boiling heat, which had no immediate effect, but on dropping in a little nitrous acid, solution began with violent disengagement of nitrous gas. When every thing soluble was taken up, the solution consisted of a clear green liquor on which the sulphur was floating. The insoluble part amounted to 38 1-2 grains, 37 of which were dissipated by calcination and were sulphur, leaving 1 1-2 of silex behind. The solution was divided into two parts, one to ascertain the copper, the other the iron.

Into the former a bar of polished iron was immersed, and by rest 78 1-2 grains of copper were precipitated.—The other half was supersaturated with ammonia, which first precipitated both the iron and copper, and then redissolved only the copper, leaving 3 grains of oxyd of iron, equal to 2 1-2 of metallic iron. Hence the iron, cop-

*Essays, vol. i.

per, silex, and sulphur were separately estimated. The copper is presumed to be in the metallic state in this ore on account of the violent evolution of nitrous gas. It is to be observed that by a previous trial the ore was found by the tests before described to be free from silver and lead, that is by giving no precipitate either with muriat of soda, or sulphat of soda.

The variegated copper ore was assayed by the same eminent chemist in nearly the same manner. On account of its colour and its making much less effervescence with nitric acid, a portion of oxygen is supposed to be combined with it.

The same was assayed in the dry way by being mixed with one-fourth of its weight of charcoal and roasted, then mixed with a fourth of colophony or rosin, and thrice its weight of black flux, and well fused. The result was a button of copper, but 10 per cent. less than the quantity of metal obtained in the moist way.

The yellow hæmatitic copper ore and the grey vitreous ore from Cornwall, were analyzed by Mr. Chenevix* nearly in the same manner as above described, only the whole solution was supersaturated with ammonia, and the copper separated from the ammoniated solution by boiling with potash, in the form of the black oxyd, of which 100 parts were estimated as equal to 80 of copper.

Ore of Silver, Copper, Iron, Antimony and Sulphur.

Klaproth's analysis of the Fahlerz† deserves a short notice on account of the skill with which it was managed.

The ore was first digested repeatedly with nitric acid, which dissolved somewhat less than half. From the solution muriat of soda separated some silver, and it was then tried for lead by sulphat of soda. It was next supersaturated with ammonia whereby a precipitate was left, which by subsequent treatment was found to consist of

* Phil. Trans. vol. 91. † Essays, vol. 1.

iron with a little alumine and silex. The ammoniated solution which now only contained copper, was supersaturated with sulphuric acid, and the copper separated by iron.

The first residue untouched by the nitric acid (amounting to more than half the ore) was then digested with muriatic acid, which dissolved nearly half, leaving a residue which by subsequent fusion with alkali was found to be silex, still holding a minute portion of silver. The muriatic solution was evaporated, during which it deposited a few small crystals of muriat of silver, after which water was added, which separated an abundant white oxyd, which was found by various trials to be antimony.

Oxyds and Carbonated Oxyds of Copper.

The purest native oxyd of copper is the red octohedral ore from Cornwall. This appears to consist of nothing but copper and oxygen, but, according to Mr. Chenevix,* the copper here exists in a less state of oxygenation than in any other known ore of this metal.

One hundred parts were totally dissolved in nitric acid with copious effervescence of nitrous gas. The pure blue solution was evaporated to dryness, muriatic acid was added, and a second time evaporated to expel the remaining nitric acid, and convert the salt to a muriat. This latter diluted with water gave up 88.5 of copper to a plate of iron immersed. Hence it is found to consist of 88.5 of copper and 11.5 oxygen. The particulars of this analysis will be further noticed when describing the oxyds and muriat of copper.

The pure carbonated oxyds of copper consist of carbonic acid, oxygen, copper and water. With almost any acid they effervesce strongly, and give out their carbonic acid.

Fontana was the first who clearly shewed the presence

* Phil. Trans. for 1801.

of carbonic acid in these ores. By distilling malachite *per se* in a glass retort, and collecting the products, he obtained some pure water, and a large quantity of gas, which extinguished a candle, precipitated lime-water, and by various tests was found to be carbonic acid.

The Siberian malachite analyzed by Klaproth will furnish another example of analysis. A hundred grains calcined in a moderate red heat in a covered crucible lost 29 1-2, which therefore is the quantity of the carbonic acid and water. Another 100 grains were dissolved in dilute sulphuric acid, and lost by effervescence 18 grains, which, subtracted from the 29 1-2, leaves 11.5 for the water.—The sulphuric solution decomposed by metallic zinc gave 58 grains of copper. Another portion of the malachite was dissolved in nitric acid, and the precipitate by ammonia was entirely redissolved by an excess of this alkali, shewing therefore the total absence of iron. Lastly, the quantity of oxygen united with the copper is inferred to be that which must be added to the 58 and 29 1-2 to make up the 100, namely 12.5.

The native carbonat when pure has precisely the same composition as the artificial, as Proust has clearly shewn, and will be presently mentioned.

Arseniat of Copper.

The composition of the different species of this family of copper ores as far as it is hitherto known is extremely simple, the ore when separated from its matrix containing nothing but arsenic acid, oxyd of copper, water, and sometimes a portion of iron. The arsenic acid is best estimated by uniting it by stronger affinity with some other metal where it makes an insoluble salt of a known and invariable composition. Lead is the best fitted for this purpose, so that when the nitrat or acetite of lead is added to arseniat of copper, a soluble nitrat or acetite of copper is formed, together with a white insoluble precipitate of arseniat of lead. By preliminary experiments Klaproth found that

100 grains of solid arsenical acid gave 297 grains of solid arseniat of lead after moderate drying, and hence 100 grains of the arseniat contain 33.66 of arsenic acid.*

For the analysis, the ore being first dissolved in nitric acid, the solution was accurately neutralized with carbonated potash, and then acetited lead was added till all precipitation ceased, a little of this salt remaining in excess. The precipitate of arseniated lead when washed and dried indicated the proportion of arsenic acid in the ore. The solution now contained acetic and nitric acids, united with oxyd of copper and potash, and a little acetited lead; from which the lead was first separated by sulphat of soda, that precipitated it in the form of an insoluble sulphat, after which a little sulphuric acid was added to engage the copper, and this metal in its turn was separated by polished iron in the usual manner. The copper however is thus obtained in the metallic state, but in the ore it is an oxyd, and therefore one-fourth of the weight of the copper must be added for oxygen, that is (as in the actual analysis) for 40 parts of metallic copper, 50 of the oxyd of copper must be estimated. It is necessary to neutralize the nitrous solution at first, as the arseniated lead is very soluble in acids, and therefore would not otherwise be properly collected.

Where iron is suspected in the ore, the solution instead of being finally precipitated by polished iron may be decomposed by ammonia, and the copper separated from the iron by an excess of the alkali.

As many acids form a white precipitate with the solutions of lead, the powder in question is proved to be arseniat of lead by digesting with sulphuric acid, which displaces the former acid, and leaves it uncombined in the liquor; and arsenic acid is detected by various methods mentioned under that article, particularly by giving

* Klaproth, vol. ii. 148.

a brick-red precipitate with nitrat of silver, the arsenic acid being first neutralized with soda.

Mr. Chenevix analyses the arseniats of copper in the same general way, but with some variations.

The ore (previously heated moderately to expel and estimate the mere water) is dissolved in dilute nitric acid and nitrat of lead poured in. The solution (containing an excess of acid and therefore holding some of the arseniated lead dissolved) is then evaporated nearly to dryness, and alcohol added to complete the separation of the arseniat of lead. After which the copper is decomposed by potash, and is obtained in the state of the brown oxyd.

Muriat of Copper.

The composition of this singular ore, found hitherto only in Peru, was ascertained nearly at the same time by Proust, and by Rochfoucault, Beaume, Fourcroy and Berthollet, a committee nominated for the purpose by the French Academy. The experiments are instructive.

The ore thrown on hot coals burns with a beautiful blue and green flame, whereas malachite, which it most resembles in appearance, gives only a faint green flame. Distilled *per se*, malachite gives no other volatile product than carbonic acid and water; whereas the muriat gives in the same process a quantity of oxygen gas with only a very small proportion of carbonic acid, and a green liquor strongly smelling of muriatic acid and proved to contain copper by giving a fine blue with ammonia. The residue in the retort was a brown oxyd of copper. This when exposed to air turns green, shewing therefore that it is not a simple, but a muriated oxyd. Part of the muriat of copper therefore is volatilized, as it is well known that this salt readily rises in distillation. The muriatic acid however is not sufficient in this ore to saturate the oxyd of copper, and hence by simple boiling in water only a small portion is dissolved, which gives luna cornea with nitrat of silver.

This ore was analyzed by Klaproth in the following simple manner, its general contents having been ascertained by the above-mentioned experiments. One hundred grains of the ore were dissolved in nitric acid without heat, during which about 1 1-2 of iron ochre was deposited. It was then diluted and nitrat of silver added to ascertain the quantity of luna cornea. Of this last, 64 1-2 grains were obtained, of which 10 grains were muriatic acid, according to separate experiments by which it appears that 100 grains of silver form 133 of luna cornea, and of the 33 grains additional weight, 12 1-2 are oxygen, and 20 1-2 muriatic acid. The copper was then precipitated as usual by iron, and weighed 57 1-2 grains in the metallic state, equal to 73 of the brown oxyd. Klaproth does not consider the iron however as essential to the ore, and therefore excludes it from the estimate.

Phosphat of Copper.

This rare metal was analyzed by Klaproth in the following way. It was first dissolved in nitric acid, which made a clear blue solution, leaving untouched 16 parts out of 100, which were quartz. The solution was then just saturated with potash to engage any excess of nitric acid, and acetited lead was then added, which gave a copious white precipitate, and a small excess of the acetite was used to ensure the complete precipitation. This white insoluble salt from appearance might be either sulphat, or arseniat, or muriat, or phosphat of lead, but it was proved to be the latter by the two following tests: 1st, when fused by the blowpipe, in the moment of cooling it assumed a garnet-like form with shining surfaces, which sudden crystallization is peculiar to phosphat of lead; and 2dly, when digested with dilute sulphuric acid, sulphat of lead was formed, and naked phosphoric acid remained in the liquor, which being neutralized, partly by soda and partly by ammonia, gave the well-known microcosmic salt. The native phosphoric acid was there-

fore separated from the copper in this analysis, and from 100 grains (exclusive of the quartz) 138 grains of phosphat of lead were formed, the phosphoric acid of which was estimated from other experiments to amount to 30.95 grains. The cupreous solution was then treated with a little sulphat of soda, to separate the lead from the excess of the acetite remaining; some naked sulphuric acid was then added, and the copper was separated by iron in the metallic state, which (increased in the proportion of 125 to 100), was found equal to 68.13 of oxyd of copper.

The above analyses include almost all the important ores of copper, except those in which it is combined with tin, which will be treated of under that metal. It may be mentioned however that the most accurate way of separating copper from tin appears to be to immerse in a solution of both metals a stick of tin, which will precipitate all the copper, whilst the loss of weight of the immersed tin subtracted from the entire quantity of tin afterwards obtained from the solution, will indicate the quantity of tin belonging to the ore. [1 *Aikins Dic.* 327.

Of the Reduction of Copper Ores.

The only ores of copper in fact that are wrought in the large way, and from which the copper of commerce is for the most part supplied, are the sulphureous and arsenical ores of this metal. The method of reducing them, though consisting of a great number of processes, on account of the powerful affinity, both of the arsenic and sulphur, is yet upon the whole very simple, being little more than repeated roastings and fusions, till the metal has acquired the necessary ductility, for it is never brought to a state of absolute purity, and the commoner sorts contain both arsenic and antimony, in such proportions, as to be wholly unfit for alloying with either gold or silver.

The rough ore, if simply sulphureous, is broken into pieces not larger than an egg, and separated as much as

possible from the adhering earthy impurities; after which it is piled in large kilns, and heat being applied at the bottom, the whole mass becomes gradually heated, and a large portion of the sulphur sublimes out, and may be either collected by proper flues, or allowed to escape; this first process occupies about six months, at the expiration of which time, the evaporation of the sulphur ceases, and when the ore has cooled sufficiently, it is in a fit state to be smelted.

If, however, the ore is largely combined with arsenic, it is not capable of keeping up a long combustion of itself, nor is the heat thus generated adequate to the expulsion of the arsenic; a somewhat different method, therefore, of roasting must be had recourse to. For this purpose the ore is still more carefully dressed than in the former case, and is reduced to pieces not larger than a hazlenut. It is then spread on the floor of a large reverberatory furnace, and exposed to a dull red heat, with frequent stirring, in order to offer fresh surfaces to the action of the flame. The arsenic and sulphur by this treatment are rapidly driven off, and in about twelve hours the roasting is completed.

The ore is now transferred into the fusing furnace, which is a reverberatory of the common construction; a little bruised lime-stone is generally added by way of flux, and in the course of four or five hours the fusion is usually complete; the slag, now of the consistence of soft dough, is raked off, and the copper is discharged through a plughole into water, by which it is reduced into small drops or grains.

The copper, however, though in the metallic state, is still very impure, being largely mixed with sulphur and arsenic, which give it a grey colour, and render it perfectly brittle. In order to separate these impurities, it is remelted and granulated twice more, or oftener, a considerable quantity of slag being separted at each fusion; but as

this slag contains some copper it is not thrown away, but worked over again with the next charge of calcined ore. The number of fusions and granulations entirely depend on the quantity of impurities, and the obstinacy with which they combine with the copper; but when these processes have been repeated the requisite number of times, the granulated mass is melted and cast into pigs. These again are broken to pieces, and roasted for one or two days in a low red heat, and again melted and roasted several times, till the metal approaches to the state of malleable copper. It is now cast into oblong masses, about 14 inches in length, and is fit for the refining furnace. In this it is again melted, with the addition of a little charcoal, till it acquires the necessary degree of malleability, and thus becomes saleable copper.

Sometimes lead is employed with good effect in the refining of copper, as it combines with, and scorifies iron, and the other easily oxydable metals in preference to copper. For this purpose the rough copper is spread on the floor of a furnace, and when it is in complete fusion, about 6 or 8 *per cent.* of lead is thrown in, and well mixed with the rest. In a short time the surface of the melted metal becomes covered with a semi-vitreous blackish-brown scoria, consisting of the mixed oxyds of lead, iron, and other impurities, together with a little copper. The first scoria being removed, a second is formed, which is in like manner scummed off, and so on successively, till, after ten or twelve hours the copper is sufficiently purified: this is ascertained by the thinness of the film with which the melted copper is covered, and by its being of a brick-red colour, also by the circumstance that if a rod of polished iron is dipped into the fused mass the portion of copper that adheres to it immediately falls off when the rod is dipped in cold water.

So far the editors of Rees's Encyclopædia: but the process is not so easy, and deserves to be treated more at

length; I shall therefore present the reader with other accounts, not regarding the chance of some tautology, and repetition.

Reduction of the Ores.

The reduction of copper ores in the large way is on the whole a very simple business, being little else than a succession of roasting and reducing processes of the simplest kind, till the metal acquires the desired degree of malleability and purity. It is to be observed that both arsenic and sulphur adhere to copper with great obstinacy, even long after it has assumed the appearance of a pure regulus, and even in very small proportion they make the metal brittle, hard, and difficult to work.

There are scarcely two works in which precisely the same order is observed in the different reducing processes (supposing the quality of the ore to be the same) and as the manufacturer is generally satisfied with that which has been long established and is attended with ordinary success, he seldom enquires whether the labour may be shortened or the expense diminished.

The sulphuret of copper which is obtained in such vast quantities at the Parys mine in Anglesea, is wrought into rough copper in the following manner. The ore is dug up in large pieces (being mostly obtained by blasting) and is first broken into smallish lumps by the hammer, chiefly by women and children, and put into a kiln from which proceed flues that open into a very long close pent-house gallery to collect the sulphur. The kiln is covered close, and a little fire is applied to the mass of ore in different places, whereby the whole is gradually kindled. The sulphur then rises in vapour to the top of the kiln, and thence through the flue into the long gallery, where it slowly condenses, and is afterwards brushed out and further prepared for sale. The mass of ore when once kindled continues to burn of itself with a smouldering heat for about six months, during which time the sul-

phur-chamber is cleared out four times, after which the ore is sufficiently roasted. The old sulphur-chambers are on a level with the kilns and of the same length and height, or in fact they are a prolongation of the kilns: but the more modern and improved chambers are like lime-kilns, the ore being at the bottom, and the sulphur subliming at the top, with a contrivance to take out the roasted ore, and thus to keep up a perpetual fire.

The richest part of the roasted ore is exported without further preparation, but the poorest part is smelted on the spot. It still contains a vast quantity of sulphur and other impurities. The smelting houses are a range of large reverberatory furnaces, thirty-one of which are under the same roof, ranged side by side in a single long row. They are all air furnaces, the chimneys of which are 41 feet high, which causes a most powerful draught through them. The fuel is coal, which is burned on a grate at the anterior part of the furnace, and the flame in drawing up the chimney passes over the bed of the reverberatory, into which is put 12 cwt. of the roasted ore, previously mixed with a small portion of coal dust. The ore is here melted and reduced into a very impure regulus, and when sufficiently fused it is drawn off through a plug-hole into earthen moulds. A single charge of the furnace, or 12 cwt. yields 1-2 a cwt. of rough copper, which by further purification affords about 50 per cent. of pure malleable metal. The furnaces work off a single charge about every five hours.

The copper furnaces in Cornwall are also of the reverberatory kind. The ore when drawn up from the mine is first broken into pieces no bigger than a hazle-nut, which operation is called *cobbing*, and the better sort is picked out by hand. The reduction begins by the process of roasting in large reverberatory furnaces 14 feet by 16, the bottom or bed of which is made of fire-bricks and covered to the thickness of about two feet with silicious

sand, which runs together by the heat into a semi-vitrified mass. The chimney is from forty to fifty feet high, which causes such a powerful draught that the arsenic and sulphur separated during the roasting pass almost entirely through the chimney into the open air, none of it being collected as at Anglesea. The ore is spread over the bottom of the furnace about a foot thick, being thrown in through a kind of funnel or hopper just above. The fuel is Welsh coal, which, as usual, is burnt at the anterior part of the furnace, and its flame draws over the surface of the ore in its passage to the chimney. In this furnace, which is called the calcining furnace, and is the largest of all, the ore is roasted without addition with a dull red heat for 12 hours and is frequently in that time stirred with a long iron rake, introduced through a hole at the further end of the reverberatory, to expose fresh surfaces to the action of the flame. The ore is not melted here, but when roasted sufficiently, it is carried to another furnace exactly similar to the former, but smaller, that is, about 9 feet by 6, and here it receives a fusing heat, but still without any addition, except that when the slag does not rise freely, a little calcareous sand is thrown in. At the end of every four hours the slag is raked out; it is then of the consistence of soft dough and is laded into oblong moulds, and a little water is sprinkled upon it to make it sink down, after which the moulds are quite filled with it, and when cold it makes hard solid blocks of slag about 14 inches long and 12 deep and broad, which are used for building. After the slag is raked off, a fresh charge of calcined ore is let down into the reverberatory, and the copper is tapped off by a hole in the side of the furnace, which before the fusion had been stopped up with a shovel full of wet clay mixed with about a fourth of new coal, which prevents the clay from hardening too much, so that the hole may readily be opened by an iron pick.

The rough copper as it runs from the surface is con-

veyed by a gutter into a large kind of bucket suspended by chains in a well through which a stream of water is passing, and here, in falling into the water, the metal is granulated, which takes place without explosion or danger, and it is then drawn out by raising the bucket.

The copper is still however extremely impure, though apparently in the metallic state, being grey and perfectly brittle, and still mixed with arsenic and sulphur, to separate which is the work of several subsequent processes. It is then remelted and granulated twice more, or oftener, each time throwing up a slag in the furnace, which is removed before the plug-hole is tapped; but as this slag contains some copper, it is not cast into moulds as the first, but worked over and over again with the fresh charges of calcined ore. The number of fusions and granulations is entirely determined by the nature of the ore. The granulated mass is then melted and cast into pigs, which have a blistered appearance on the surface, and are broken up and roasted for one or two days in a low red heat, and again melted and roasted as before for several times till the metal is considerably purer, and at last is cast in oblong iron moulds about 14 inches in length, when it is removed to the *Refining Furnace*. Here it is again melted with the addition of a little charcoal, till it is brought to a sufficient purity to bear the hammer, and is now good saleable copper.

It is observable that in the former process when the crude and brittle metal is cast in sand in the form of large pigs or ingots, the best part of the copper rises to the surface, and when cold may be knocked off with a hammer, forming a brittle crust about three-quarters of an inch thick, of a grey colour and a steel-like fracture.

Thus by a series of successive calcinations and fusions in the simplest manner possible, the common copper ores are freed from arsenic, sulphur and earthy matters, and gradually brought to the state of malleable copper. Where

a variety of ores from different places and of different species are brought to the same smelting-house (which is the case in many of the houses at Swansea and different parts of the Bristol coast) much technical judgment is exercised in sorting the ores and distributing the charges for the furnace in such a manner that the more fusible will assist the reduction of the refractory, and the poorer will be made more worth working by the addition of a portion of the richer ores, and the like.

The subsequent operations whereby the ingots or pigs of malleable copper are formed into sheet copper, wire, nails, bolts, cauldrons, and an infinite variety of manufactured articles, do not come within the province of pure chemistry: it may be sufficient to observe that the hammering renders the metal much more uniform, close, and ductile, but this requires to be frequently alternated with annealing at a full red heat, to prevent the metal from cracking under the powerful pressure to which it is exposed. Immediately after the last annealing, the copper plates are quenched in urine, which somewhat hardens the surface, and gives it that redness which is considered by the merchant as one mark of the purity of the metal.

In the reduction of the copper ores of Neusol in Hungary, lead is used in the refining part of the process* in the following manner: the rough copper is spread on the bed of a furnace, and when it has been six hours in fusion, some lead, in the proportion of from 6 to 8 per cent. of the copper, is thrown in, which immediately begins to vitrify and to form a thick scoria along with the impurities of the copper, which is scummed off successively till the whole is exhausted and the copper remains fine and clear. This process lasts from ten to twelve hours, with fifty quintals of raw copper. The scoriæ retain a portion of copper, which makes it answer to work them again.

* Jars Voyages Metall. tom. 3.

The power which the vitrified oxyd of lead has to scorify all metals, except gold, silver and platina, is amply shewn in the process of *Assaying*, and hence it must happen that in refining, some of the copper becomes oxidated together with the lead; but the same process of assaying shews that copper requires a large portion of lead for this purpose, and therefore the latter metal in so small a proportion as 6 to 8 per cent. is probably a most useful addition where not too expensive. For of all the common imperfect metals, copper is that which scorifies and oxidates with most difficulty when in fusion, and therefore the same method, with some little variety, may be practised to separate lead and tin (for example) from copper, as any or all of these metals from silver or gold, care being taken in the former case not to carry the scorification beyond what is necessary to separate the more easily oxidable metals from the copper which then remains in the metallic state. This will be further noticed in the succeeding article of *Alloys of Copper*, and the purification of bell-metal. After the greater part of the lead has been worked off as often as is judged necessary, the remaining copper must be kept for a while longer in fusion, to throw up the last portions of lead that may adhere. In assaying gold or silver the total expulsion of the lead is known by the fine metal becoming at once brilliant on the surface, but in refining copper this appearance can never take place, as the copper itself always forms a thin oxyd on its melted surface; and therefore, to judge whether it is pure, the workman dips a polished iron rod in the melted mass, and draws out a portion of copper adhering to it, which, if pure, immediately falls off when the rod is dipped in water. The colour of the scoria is also another test. While the copper remains impure and alloyed with iron, sulphur, &c. the vitrified oxyd on the surface is black or of a dirty brown, but the scoria of pure copper is red, and also is readily separated from the iron when cold, leaving no stain behind.

The plates of fine red copper, called *Rosette Copper*, are made in the following way.* When the refined copper is found by the way just mentioned to be sufficiently pure, the surface of the melted metal is well scummed and suffered to cool till it is ready to fix, at which time a workman brushes it over with a wet broom, which immediately fixes the surface and causes a thin plate to separate from the still fluid metal below. This plate is taken off and thrown into water, where it takes a high red colour, and the same process of wetting the surface is repeated with the remaining fluid metal successively, till the whole is reduced to these thin irregular plates.

A considerable quantity of copper is obtained from the springs of native sulphat of copper or blue vitriol, which are found in most copper mines or flow from hills containing this metal. To obtain it, the vitriol water is pumped up into large square open pits, two or three feet deep, made with rammed clay, into which is thrown a quantity of refuse iron of any kind, and suffered to remain for a considerable time, during which the iron is dissolved, displacing by superior affinity the copper which is precipitated in the form of a brown mud. When the water is thus exhausted of its copper, the pits are raked out, and the oxyd collected from them is simply dried in the sun. It is then fit for reduction in the reverberatory furnaces in the usual manner. This is by far the richest material employed, for, though containing some clay and iron mixed with the copper, it yields on an average full 50 per cent. of pure metal, and therefore it is seldom smelted by itself, but mixed with the poorer ores, some of which contain no more than five per cent. of metal.

Many of the finest copper ores contain so much silver as to make it worth while to extract this last metal by a separate operation, which will be described under the ar-

* Macquer Chem. Dict.

ticle *Silver*. In all the different roastings and reductions necessary to bring the copper to purity, the silver remains united with it. [*Aikin*.

I have translated the following account from Hellot's Schlutter, v. 2. p. 496; it is the substance of the best methods detailed by him. His work, like that of Jars, who wrote long after him, contains not only detailed accounts of the processes of various works, but plates of the various furnaces in use. I give none of these, being persuaded that the well known and long-approved Cupola furnace of the lead and copper works of England, is preferable.

At the Bristol foundery, they smelt the copper ores of Cornwall, Devonshire and New York, in a reverberatory furnace such as is used for lead. The ore is broken into small pieces of the size of a walnut. The hearth is made of sea sand: the basin that receives the metal let out, is made in the same way. They are baked by the heat of stone coal. The ore is also heated in the same manner which serves also for roasting. This poured on the hearth through a hole in the arch by means of a hopper, and the hole is then closed: it is thus fed with four quintals of ore every four hours. The coals are lighted on a grate on each side of the hearth, and the flame reverberates on the ore from the arch, as in a red-lead furnace: the ore is thus roasted and then melted. The scoriæ are raked off by an opening left for this purpose. The matt, or crude metal, is run off every 24 hours. This furnace is kept in blast for a twelve month together.

Secondly, The *crude metal* broken in pieces, is placed on the same kind of hearth in another furnace, and kept under the flame of the reverberatory for 18 hours: it is then let out into a basin or reservoir of sea sand, sometimes cemented by being mixed with finely powdered glass, and then exposed to strong heat. This operation,

termed roasting, is repeated 8 and sometimes 12 times before *black copper* can be obtained. When this appears, it is let off, and run into ingots, which are again exposed to the reverberatory till the copper is quite purified. This is let off and granulated by falling into water while in a melted state.

Such a reverberatory may be worked by wood as well as coal.

The hearth and basin (catin) may be made of sand as above mentioned, with a thin coating of pounded and sifted glass, which when melted, unites the surface into a compact body. Sometimes they are made of one part by measure of clay, and two parts or more of charcoal dust with one measure of well burnt pounded brick or fire stone: all these are moistened, well mixed, and well beaten with flat wooden and iron pounders, and rammed.

The flux is sometimes (in England) common salt, and sometimes broken glass, and scoriæ.

Refining.—This is for the purpose of scorifying any iron, lead, zinc, tin, antimony or cobalt that the metal may contain.

The furnace is in shape of a table 2 feet 6 inches from the ground, 6 feet 6 inches wide and 4 feet 6 inches deep. At the distance of 9 feet 3 inches from the ground, an arch is raised, and on this arch a chimney, and the wall against which the furnace is supported. At the sides of the furnace, a door-way is left, the height of a man, to clear the surface of the melted metal. The bottom should be as high as the underside of the air pipe or tuyere (tweer) and hollowed out by means of an iron cutting ring with a slanting edge, 6 feet 6 inches diameter and 9 inches deep: well beaten, and made smooth, and then dried by gradually heating it. A strong blast from a pipe of one inch diameter should play full on the surface of the melted metal covered with coals. There must be also a hole left near the tweer

to introduce the Trial Iron into the metal exposed at the nose of the blast. The metal being perfectly melted, the blast should be continued, with fresh coals for half an hour: the copper being less oxydable than the metals mixed with it, these rise in scoriæ to the top, and are removed occasionally by the refiner, by raising them with pointed sticks, and then raking them off as quickly as possible lest the metal should cool, first removing the hot coals all round and stopping the blast: the surface is again covered with hot coals, and the blast renewed. When the surface affords no more scoriæ, the refiner tries the metal with the iron which is a rod of about 3 feet 6 inches long, about as thick as a finger, and pointed with polished steel. This is heated moderately, and plunged quickly into the melted metal of which a part sticks to the iron. If it removes easily from the iron, and is of a good colour and all smoke is over, the fire is continued enough. If it sticks too hard to the iron, the metal is not yet pure.

If pure, the surface of the copper is sprinkled (not splashed) with water, and the congealed plates are taken off with pinchers, and is the rose copper, or Rosette.

As the blast strikes the copper, care should be taken that it does not blow away the coals, which also may now and then be sprinkled to prevent their flying off. Care also should be taken to keep the mouth of the bellows clean, and the sides of the basin should be so managed that the inclination of the melted matter should be slightly toward the bellows or tweer.

If there should not be metal enough to fill the basin so that the blast shall strike on the melted metal, a charge of copper already refined should be put in, or the whole mass may be stirred upward, with a stick of wood, which when burnt away may be supplied by another.

When the Rosettes are taken off by the pinchers, they should be plunged into water obliquely by the edges, not

flat, otherwise some parts of the hot copper not quite fixed, may be thrown off against the workman.

The essay should be frequent: when finished, the copper throws out small globules and is red, and filamentous with few yellow spots. The scoriæ from being black, become brown and brownish red, and emit no smoke.

When the refining is carried further than is necessary, the plates are thicker, the under side also is full of pointed drops, but the metal is not the worse.

If the copper is not sufficiently refined, the plates are of unequal thickness, and have inequalities of a dark colour near the edges, or the metal has pale coloured spots in its fracture.

The refining hearth may be near the foundery furnace: it may be of fire stone, fire brick, or brasque.

The refining occupies from an hour and a half to two hours.

If the basin must be emptied, it may be done by ladles well covered with clay inside and out.

The scoriæ should always be so removed, that the blast may strike the surface.

The hearth ought to be examined and mended after each operation.

There should be an iron ring to retain the coals.

I shall now proceed to give the processes used at the mines of Fahlun, in Sweden, and Tresburgh near Brunswick, in Germany, from 3 Jars Voyages Mineralogiques.

I select these, because the Swedish copper is very good, and because the works at Tresburgh were under the direction of M. Cramer, whose skill is well known. At Fahlun, they do not find it necessary to wash the ore: at Tresburgh it is washed, after being broken, and sorted, and sifted.

At Tresburgh, owing to the quantity of fluor spar that accompanies the ore and assists the fusion, the ore is not

previously roasted. But at Fahlun and many places in Germany, the ore is roasted in the open air, upon a levelled platform of earth about 14 feet long by 7 feet 6 inches broad. The bottom is well covered with billets, on which the ore is laid and heaped up to the height of about 5 feet 6 inches. The more sulphurous and pyritical pieces are in the middle, the richer on the outside. The sides are covered with the dust of the ore sufficiently thick to retain the heat. Holes are made at the top for the sulphur and fume to escape. The fire is gradually kept up for a month or more. The mass is then opened, and the ore carried to the furnaces for *smelting* the copper into a *matt*, which is afterwards carried to the refining furnace.

Of these furnaces, both Schlutter and Jars give plates, (Schlutter plate 32, Jars vol. 3. plate 3). The smelting furnace at Fahlun, is made thus: upon an arch open at each end, surrounded by masonry (the arch being preferred to avoid the quantity of moisture which solid masonry would furnish) a platform of brasque, a composition, half clay and half sand, is laid and well beaten; four or five feet square. On this another composition is well beaten of equal parts of clay and charcoal dust. This is hollowed out to 15 inches deep, leaving the two layers of brasque at least six inches thick. At this level of 15 inches from the bottom is placed the nose of the tuyere. The bottom has a gentle inclination to allow the melted matter to run and gather to one end. The furnace is about 3 feet by 3 feet 6 inches and about 4 feet 8 inches high. It is well dried by being gradually heated. It is charged with charcoal and ore. The front is made up with fire stone or clay, and the furnace tapped as occasion requires.

At Fahlun, sometimes the ore is roasted in furnaces appropriated to this purpose, where it receives seven or eight firings.

The matt, or produce of the first smelting of the roasted ore, is again melted in a similar furnace of smaller dimensions, where it produces large pigs of black copper. The details of all this are best given in 2 Schlutter, p. 492, who also treats at large on the refining of copper.

The refining furnace, is about 3 feet 8 inches by 3 feet 2 1-4 inches deep. The tweer of copper has an inclination of about 25 degrees, and the blast is directed toward the most distant part of the furnace. The basin of the furnace, is made of a composition of two parts well tempered clay, beaten up with one part charcoal dust and one part cinders. Of this composition or brasque there are three layers. When well made, it will last for three or four refinings. The loss amounts to ten per cent. The copper is taken out in rosettes as above described.

At Tresburgh the furnace is 5 French feet high, 3 feet deep, 16 inches wide at one end, and 21 at the other where the tweer enters, which is not elevated above 4 or 5 inches above the basin of the front hearth.

The copper undergoes repeated fusions at the refining, till it becomes pure, which is tried as has been already mentioned in the case of the English furnaces.

The following note I copy from some manuscripts lent me by my much respected friend Dr. Hunter of Philadelphia.

Copper Refined.

Memorandum of a process for refining *copper* at one smelting, given by Mr. Francis Da Costa. The kopperpys (the ore) are put into an air furnace, which is first heated slowly to give an opportunity for the sulphur and other volatile metallic substances such as antimony and arsenic to evaporate—half an hour afterwards increase the heat to fusion. Then throw on the surface of the metal a layer of fine white clear sand which melts and dissolves

a mass of cinder at the surface. When formed take it out with a scraper and let the metal remain in a fluid state long enough to allow the remaining oxydable substances to come to the surface, and then renew the operation with sand should that second operation prove necessary; and let the cinder be again scraped out. Then throw on the surface of the fluid copper, powdered charcoal to carry off the oxygen remaining. When this charcoal is burnt down, dip into and stir the copper well with a stick which whilst burning, occasions an ebullition which throws up to the surface those parts of the metal, that had not been in contact with the coal, and throw some more coal upon it and renew the operation until you ascertain, that the refining is complete which is easily done by taking out a little of the melted copper with a small ladle; cast, cool and break it, if the metal appears silky and of a good colour, the metal is pure and fit for any purpose—when cast into large thin moulds, it requires to be very hot, and at the same time the moulds ought to be very dry, to prevent accidents, or the losing the intended casting piece. Mr. Da Costa believes that this process depends on the difference of affinity between copper and iron, which last is the principal impurity in the copper brought from the Spanish main.

N. B. G. H. has examined several samples of copper brought from Spanish America and never found any iron in them—he generally found sulphur and antimony.

Perhaps powdered magnesia (manganese) would have a good effect in separating the semi-metals, which are commonly found in a small proportion in copper in pigs, and thereby facilitate the malleability of it, by stirring it well with the melted copper. Nitre is too dear.

Having now given some ideas of the mode of working copper ores, from writers who have treated on the subject, I will give the substance of my own notes, taken on a

tour to Amlwch or Amluch, in the isle of Anglesea which I visited in the year 1791, solely from curiosity to see the Parys copper mine of that island.

We (I and Mr. Baker, a proprietor of oil of vitriol works, who wished to purchase sulphur at Anglesea; the Mr. Baker, who combining some experiments of my own and Mr. Charles Taylor's, struck out the most perfect and compendious system of bleaching yet known) went to Chester from my residence at Altringham.

At Chester, a town of little trade, *for it is a borough or corporation town*, there is nothing remarkable but the porticoes of the street, hollowed out of the rock. The country people of Wales, sell there, their home made woollen stockings, such as are here sold for 75 cents, at 10 pence sterling per pair by the dozen. (1791). It will be a long time before the raw material wool, is as cheap in America as in England.

After leaving Chester, toward Conway, we found nothing but Welch spoken by the commonalty: I know of nothing so amusingly strange to an English ear, as a Welch scolding match, with which we were more than once entertained. Not a word of English from thence to Anglesea "dim sausenick" I do not understand Saxon, or English, was the common reply. There is no such utter ignorance in this country.

After visiting the ruins of Conway Castle, we took chaise (the Landlord of the inn refusing to let us have one unless with four horses) toward Anglesea, over Penman Maur.

The road is dug on the side of the rock, and imperfectly made. A wall about five feet high protects the traveller from an abrupt precipice of about a hundred and fifty feet below, the sea for a great part of the way washing the foot of the rock; on the side of which, we had to pass over a road from ten to sixteen feet broad. We slowly

followed the stage coach; which was conducted with great caution by the driver, over a part of the road where the mountain overhung the carriage; the wall was to the right, and a large shelving rock not blown up in the pathway of the road, required all the circumspection that could be employed. All was not enough. The coach tilted when it came upon the stone in the road; it fell upon the wall; and Mr. Baker and I, scrambled over, just in time to take the passengers out at the window on the side of the wall toward the precipice. The coach balanced on the wall. We put up at a tavern on the Anglesea side of the Menai: there as at every other tavern where we stopt between Chester and Anglesea, a harper introduced himself: and without further ceremony than the first obeisance, struck up the national tune "of a noble race was Shenkin."

We passed in our road from Chester, Holywell, a flourishing little town, containing as I think the largest spring of water in the kingdom, turning many cotton works. But I know nothing more of it.

We went to Amlwch, or Amluch as the English pronounce it. I cannot imitate by writing or by sound, the guttural pronunciation of the Welch. The English with the vulgar impoliteness of ignorance laugh at Americanisms. I confess we can do without *lengthy*, and *illy*, and *predicate:* these are not expressions, which will justify our national literature in taking what we call "*high ground.*" And notwithstanding the excellent defence made in behalf of our language by the editor of the Port Folio against the ignorant and hasty sarcasms of the Edinburgh Review, I could wish Mr. Barlow in his Columbiad, had been more sparing of his novelties in language—novelties that he may own if he pleases, but which do not belong to us. Still our representatives do not *deal in truisms*—nor do they move Mr. Speaker *to appoint a short*

day—nor are they *free to confess* that they differ from the right honourable gentleman *in their eye*, &c. &c.

But where is the civilization of Great Britain, when the Welch, the Irish, the Scotch, the Border, the Yorkshire, the Lancashire, the London, the Somersetshire, and the Cornish dialects, are mutually unintelligible to the inhabitants of each? Bring together an inhabitant of Ormskirk or Poulton in the Fylde in Lancashire, and Redruth or Truro in Cornwall, and although each would talk English, they would understand each other, about as much as an Hottentot and a Cherokee. There is no such disgrace in America. Five and twenty years may have lessened it in England, but it existed in great force at that period.

We went to the Parys mountain, which is about a mile long. It is excavated from the top downward. All is open to the day. No shafts, no levels, the ore is drawn up to the top.

The kinds of ore, are the common yellow sulphuret of copper—azure or mountain blue—malachite or mountain green (carbonats)—Black copper ore, contaminated with sulphuret of lead, black jack and calamine—sulphuret of copper or blue vitriol chrystallized, and in solution, which is pumped up—sulphat of lead, and the dog-tooth lead ore.

There is also found in small quantities, native copper—and some native sulphur.

The copper and sulphur in the best part of the ore, are about equal in quantity. The dirt of the gangue or matrix amounts to nearly one half.

In roasting the ore, the miners have a notion that the metal becomes concentrated in the middle of the lump. But this is a mistake. The middle part is most solid and heavy, because it is less acted on, by the heat, the air, and the sulphuric acid formed during the combustion of

the sulphuret. Much valuable matter appeared to me to be washed away. Much blue vitriol (sulphat of copper) and much green vitriol, (sulphat of iron) might be made there; but the copper is usually precipitated from the copper water, by immersing bars of iron in it.

In my time, they did not save the sulphur, but let it burn away. A few years afterward, Mr. Thomas Henry of Manchester, elder brother of Dr. William Henry the chemist, went to Anglesea, to contract for the sulphur that might be saved by roasting the ore with an appendage of long flues, and a chamber to save the sulphur sublimed, which he proposed to introduce. But the scheme did not answer *to him*. I believe the sulphur contained some arsenic, which rendered it unfit for the oil of vitriol manufactory.

Mr. T. Henry afterward died in South America, as a supercargo for Nicklin and Griffith of Philadelphia.

The following account by Mr. Arthur Aikin, who was at Anglesea in 1796 coincides with my own.

Process.—The ore is got from the mine by blasting; after which it is broken into smaller pieces by the hammer (this being chiefly done by women and children), and piled into a kiln, to which is attached by flues a long sulphur chamber. It is now covered close; a little fire is applied in different places, and the whole mass becomes gradually kindled; the sulphur sublimes to the top of the kiln, whence the flues convey it to the chamber appointed for its reception. This smouldering heat is kept up for six months, during which the sulphur chamber is cleared four times, at the expiration of which period the ore is sufficiently roasted. The poorest of this, that is, such as contains from one and a fourth to two per cent. of metal, is then conveyed to the smelting-houses at Amlwch-port; the rest is sent to the company's furnaces at Swansea and Stanley near Liverpool. The greater part

of the kilns are very long, about six feet high; and the sulphur chambers are of the same length and height, connected by three flues, and on the same level with the kilns; four new ones, however, have been built at Almwch-port, by which much sulphur is preserved that would have been dissipated in the old kilns. The new ones are made like lime-kilns, with a contrivance to take out the roasted ore at the bottom, and thus keep up a perpetual fire. From the neck of the kiln branches off a single flue, which conveys the sulphur into a receiving chamber, built on the rock, so as to be on a level with the neck of the kiln, that is, above the ore.

The two smelting-houses, of which one belongs to each company, contain 31 reverberatory furnaces, the chimnies of which are 41 feet high; they are charged every five hours with 12 cwt. of ore, which yields 1-2 cwt. of rough copper, containing 50 per cent. of pure metal; the price of rough copper is about 2l. 10s. per cwt. The coals are procured from Swansea and Liverpool, a great part of which is Wigan slack. From experiment it appears, that though a ton of coals will reduce more ore than the same quantity of slack, yet, owing to the difference of price, the latter is, upon the whole, preferable; the prices of the two at Liverpool being—coals 8s. 6d. per ton—slack (small coal) 5s. per ditto.

The sulphat of copper, however, is the richest ore that the mine yields, containing about 50 per cent. of pure metal. This is found in solution at the bottom of the mine, whence it is pumped up into cisterns, like tanners' pits, about two feet deep: of these pits there are many ranges, each range communicating with a shallow pool of considerable extent. Into these cisterns are put cast-iron plates, and other damaged iron vessels procured from Coalbrook Dale; when the sulphuric acid enters into combination with the iron, letting fall the copper in the

form of a red sediment very slightly oxided. The cisterns are cleared once in a quarter of a year, when the sulphat of iron in solution is let off into the shallow pool, and the copper is taken to a kiln, well dried, and is then ready for exportation. The sulphat of iron remaining in the pool partly decomposes by spontaneous evaporation, and lets fall a yellow ochre, which is dried and sent to Liverpool and London.

The sulphur produced in the roasting, after being melted and refined, is cast into rolls and large cones and sent to London. The cones are used chiefly for the manufactory of gunpowder and sulphuric acid.

Green vitriol and alum are also made in small quantities by a separate company; but to these works strangers are not admitted.

The number of men employed by the two companies is 1200 miners, and about [illegible]0 smelters; the miners are paid by the piece, and earn in general from a shilling to twenty pence per day.

The depth of the mine in the lowest part is 50 fathoms, and the ore continues as plentiful as ever, and of a quality rather superior to that which lay near the surface.

With regard to the annual quantity of ore raised, little certain can be mentioned. The Parys mine has furnished from 5000 to 10,000 tons per quarter, exclusive of what is procured from the sulphat of copper in solution; and as the two mines employ nearly equal numbers of workmen, they probably afford about the same quantity of ore.

Adjoining to the smelting-houses is a rolling-mill, upon the same construction as malt-mills, for grinding the materials for fire bricks; these consist of fragments of old fire-bricks, with clunch (a kind of magnesian clay found in coal-pits) procured from near Bangor-ferry.

The port of Almwch is chiefly artificial, being cut out

of the rocks with much labour and expence, and is capable of containing 30 vessels of two hundred tons burthen; it is greatly exposed, and dangerous of access during high northerly winds, which drive a heavy sea up the neck of the harbour. The two companies employ 15 brigs from 100 to 150 tons burthen, besides sloops and other craft, all of which lie dry at low water.

The various articles, the produce of the mines, which are exported, are the following:

I. Coarse regulus of copper from the smelting-houses.
II. The richer copper ore roasted.
III. The dried precipitate of copper from the vitriol pits.
IV. Refined sulphur.
V. Ochre.
VI. Alum.
VII. Green vitriol.

The town of Amlwch, which about thirty years ago had no more than half a dozen houses in the whole parish, now supports a population of four or five thousand inhabitants; and was at present, being market day, thronged with miners and country people. After dinner we walked along the sea shore, climbing the steep slate rocks, whence the water below appeared of a beautiful green, and so transparent as to shew the shelving rocks to a great depth beneath. [*Aikin.* 1 *Nick. Jour.* 4*to.*

From Amluch I went to Beaumaris, a seaport in Anglesea; and from thence in a vessel laden with roasted copper ore to Liverpool. At Liverpool, I went to the copper works in the neighbourhood, and also to those at Warrington and Macclesfield in Cheshire; being desirous while I was about it, to trace the manufacture as far as I could. But those works were not easy of access, and I could obtain no precise information: what occurs to me on the subject at present, is contained in the following remarks:

1. Great caution is required in washing copper ore. It is true the earths and stones adhering to it should be got rid of; but the oxyds and the carbonats of copper intermixed, are apt to be washed away.

2. In roasting the sulphurets, the lumps should not exceed the size of a hen's egg: they are usually much larger. But the sulphur is not easily dissipated from the centre of a large lump, in which the roasting is no more than superficial.

3. In my opinion the roasting can never be perfect where the combustion is supplied by the sulphur alone. I can see no good reason why the common practice of mixing coal dust with the iron ores intended to be roasted, should not be applied to the copper ores.

4. If the sulphur contain arsenic it is not worth saving. This may be known by the garlic smell and the white fumes that accompany its combustion; and by its giving a white colour to a plate of pure clean copper held over it while it burns. If the sulphur be saved, I think it is best done by horizontal flues with doors in the side; the flues terminating in a chamber, which however must have an opening, to let out gasses and vapour.

5. I know of no furnace necessary either to the smelting, or the refining of the ore, other than the common cupola or reverberatory furnace. This furnace is so contrived that the ore is melted, not by coming into immediate contact with the fuel but by the reverberation of the flame upon it. The bottom of the furnace on which the ore is placed, is concave, shelving from the sides toward the middle, where a cavity (basin) is worked to contain the melted metal: it may be laid with free stone, or with fire brick set in loam, or made of Brasque (charcoal, burnt clay and soft clay, well mixed and beaten). The roof of the furnace is low and arched, resembling the roof of a baker's oven. The fire is placed at one end of the furnace upon an

iron grate, to the bottom of which the air has free access through the bars: at the other end, opposite the fire place, is a high perpendicular chimney. The direction of the flame, when all the apertures in the sides of the furnace are closed up, is necessarily determined by the stream of air which enters at the grate and takes its course toward the chimney, whose opening commences about the level, of the melted matter, and is proportionate to the draught required. In tending thither, it strikes upon the roof of the furnace, and being reverberated from thence upon the ore, soon melts it. 3 Watson, 274.

Schlutter has given plates of the Cupola furnace: and in Rees's Encyclopædia, new edition, (chemistry plate 1) there is a section of a cupola furnace with the application of a double bellows, which I think unnecessary, though common abroad. The common lead furnace, which is also the copper furnace, is well described in that work, article " Lead." It is this:

The reverberatory (cupola) furnace employed in smelting lead, is made on the same plan with those used in puddling iron (Cort's patent process.) differing however in size, and a few other particulars. The fire is made on one end, and the flame plays over the hearth, entering an oblique chimney at the other end, which terminates in a perpendicular one of considerable height. The length of the hearth from the place where the fire enters, to the chimney, is 11 feet. Two feet of this length next the fire, constitutes the throat of the furnace. The width of the same is four feet, and its depth about six inches. The length of the fire place is four feet, equal to the width of the throat; its width two feet, and depth three feet from the grate up to the throat of the furnace. The rest of the hearth is a concave surface, nine feet long, four and a half feet wide at the throat of the furnace, seven feet four inches wide at the distance of two feet from the hearth, seven

feet two inches in the middle of the hearth, five feet eleven inches at two feet distance from the chimney, and two feet ten inches at the place where the flame enters the chimney at two apertures each ten inches square. These apertures terminate in the oblique part of the chimney, the section of which is sixteen inches square, which communicates with the main chimney, the section of which is twenty inches square. Supposing a straight horizontal line drawn from the lower plane of the throat of the chimney to the opposite side of the furnace, the lowest part of the concave hearth which is in the middle of this cavity, is nineteen inches below this line, the roof of the furnace being seventeen inches above the same line.

On each side of the furnace, are three openings, each about ten inches square for lead, but larger for copper; provided with iron doors to be removed as occasion requires. They are arranged at equal distances from each other, between the commencement of the hollow hearth, and the entrance into the chimney. The lower part of these apertures is on a level with the horizontal line above alluded to: being for the purpose of stirring and raking the ore, &c. Besides the larger openings, there are two small apertures, one below the large middle opening, and nearly on a level with the bottom of the furnace; the other under that opening which is nearest to the chimney, at some distance above the first aperture. The first, is a tap hole for the metal; the second for the scoriæ. The ore is introduced by a vessel in the shape of a hopper, placed in the roof of the furnace.

The preceding descriptions seem to me clear enough to render a plate unnecessary.

6. The smelting must be continued and repeated, till the black copper appears of its proper colour and fit for the refining; and most of the mixed metals are calcined and fused with the slag. I do not know a finer road, than

ten or twelve miles between Liverpool and Warrington, made of the slag of copper works.

7. The theory of cleansing copper from its impure mixtures, is, that it is less easily oxydable than iron, zinc, antimony or the other semi-metals. Sometimes iron is added to promote the separation of the sulphur: sometimes lead to promote the oxydation of the more oxydable metals. I cannot say in what proportions, or under what circumstances, because this must depend on the mixture to be determined by the previous analysis of the ore. Indeed, I distinctly remember, endeavouring to ascertain the mixtures and the circumstances, but without effect. It either was, or was pretended to be a great secret. Every manufactury in England, is a repository of secrets. I suspect the process would be aided by manganese.

8. I am under no hesitation in saying, that the intermixture of charcoal dust, or coak dust, with the ore both in the previous roasting, and in the furnace, and making a thin coating at the bottom of the hearth and basin, of the same material, would greatly promote the fusion and purification of the matt. Toward the last stage of the process of refining, when the oxydable metals are to be oxyded, there would be no difficulty, if need required, to introduce a current of air over the surface of the melted metal, as it appears to me. But I have not skill in the subject to do more than suggest.

Copper is an article so necessary to us at present for sheathing ships, for making distilling vessels, for vessels used for culinary purposes, for plated ware, for coin, &c. &c. that I hardly know any manufacture of such importance, after that of iron: and yet we have no smelting work for copper, or any copper mine worked in the United States. Nor shall we have, till steam engines to draw off the water and to raise the ore, become common. I would gladly undertake the article *mining*, and perhaps I

may yet venture upon it; but I have no experience except for about six months in a coal mine of my own; and I am afraid of going out of my depth.

I have said, that copper is of great moment for sheathing ships, but, I think the use of *coal-tar* will go a great way to preserve our vessels without it. The ship builders, brought it into disrepute in England for this very reason; it preserved the ships too well.

I have said that copper is of great moment for *distilling vessels;* when I come to the article "distillery," I shall make this assertion of mine very problematical: probably in the next number.

I have said that copper is of great moment for *culinary vessels;* but iron, or iron coated with Hicklin's porcelain, or with Dr. Bollman's platina, may by and by supersede copper.

Having now reduced (so far as my knowledge extends) the copper into a pure metalline state, I proceed to enumerate its properties when in that state.

Properties of Pure Copper. It is in colour of a yellowish red: it is ductile and malleable: it is harder than silver: it breaks with a hackly fracture: it is tougher than any other metal, excepting iron: it emits, when rubbed, a disagreeable smell: it has a nauseous taste: it fuses at low white heat: before it melts, it exhibits prismatic colours on its surface: it burns with a red flame edged with green when fused exposed to the air: it is easily oxyded when in fusion: it is easily tarnished by common exposure to the air: when so exposed, it combines with oxygen and carbonic acid, turning green: it unites to oxygen, sulphur, to phosphorus, to oils, to all the acids and alkalies. The specific gravity of the purest or Japonese copper is 9,: of Swedish copper 8,89: of common copper 8,6.

Preparation of sulphat of Copper, or blue vitriol of commerce.

The *sulphat* of copper, as an article of importance in several of the arts, merits our attention. For the purposes of commerce this salt has been prepared by different methods, which are,

1st. The vitriolization of the native *sulphurets* of copper, (copper pyrites).

2dly. The *formation* and *vitriolization* of artificial *sulphurets* of copper.

3dly. The evaporation of cupreous waters, and

4thly. By dissolving metallic copper in the sulphuric acid.

The first mode is practised on a large scale, particularly in Germany. That the sulphurets of copper are more difficult to vitriolize than those of iron is evident from the circumstance of the latter frequently undergoing a decomposition in consequence of exposure to atmospheric air; on this account some particular treatment is required to fit those of copper for our present purpose. Copper pyrites are broken into small pieces, alternate strata are formed with these and combustible matter; when the heap is finished it is set fire to; the fire should be moderate, and long continued; by this means the operation will be more easily managed, and more salt will be formed by the process. This roating generally lasts for 24 hours, the matter remaining is, whilst hot, thrown into tubs containing water: here it continues during 48 hours: the water should be agitated whilst it is acting on the roasted ore. The ore is now taken from the water and is roasted a second time, and is treated with water as before. We continue throwing roasted ore into the water until this last receives a fine blue colour. The solution must then be sufficiently evaporated in boilers of lead or

copper pans. On being allowed to cool the salt will crystallize.

In some places they perform the roasting during twelve hours in a reverberatory furnace.

In some countries pyrites which contain but a small quantity of copper are made use of to obtain both the sulphur and the sulphat or blue vitriol; for this purpose the ore is broken into very small pieces, earthen vessels in the form of tubes are charged with these, and then they are exposed to heat; the sulphur comes over and is received in iron vessels, connected with the earthen ones above-mentioned; the residuum is treated for *vitriol* in the manner recommended for roasted pyrites.

The second method is employed in France in the following manner: plates of copper are steeped in water, they are then withdrawn and whilst wet, pulverized sulphur is strewed over them; thus prepared they are exposed in an oven heated to redness; after remaining for some time in this oven they are withdrawn, and whilst hot they are thrown into tubs which contain water. These operations are repeated until the whole of the copper is vitriolized; when the water is sufficiently impregnated with salt, it is evaporated, &c. as above-mentioned.

According to Newmann, cuttings or waste pieces of copper are stratified and cemented with sulphur. The cover of the cementing pot is perforated with one or two small holes, and the cementation is continued with a gentle fire till the inflammable part of the sulphur is consumed. The matter is then boiled in water, and the liquor, after due evaporation, is set to crystallize. Such parts of the copper as remain uncorroded, are again treated in the manner just described.

Chaptal fused 2*lbs.* of sulphur in a crucible heated to redness: the crucible was constantly kept in the midst of the burning coals; in this situation 2*lbs.* of sheet copper

were put into it; in a very short time after, a considerable flame took place, and the copper became red; when the flame ceased, the crucible was removed from the fire; after cooling, the copper was very brittle, of a fine dark red colour, and presented a silky striated fracture; it weighed 2*lbs.* 10*oz.* The sulphuret thus formed, was divided into two equal parts, one of these was occasionally moistened with pure water, and the other with water acidulated with the sulphuric acid. The first part did not effloresce; notwithstanding every care during thirteen months, there was not the least appearance of *vitriolization:* the second parcel effloresced, and by occasionally moistening it with the acidulated water, nearly 5*lbs.* of the sulphat of copper was obtained from it.

It is said that the quantity of sulphur may be lessened by projecting it on the copper heated to redness.

When the third method is made use of, wells are dug in proper situations in such mines as are charged with cupreous waters, into these the waters are conducted from different parts of the mine; it is only necessary to evaporate them, and to set them by to crystallize.

The fourth method will certainly furnish a very pure salt. As metallic copper is insoluble in the sulphuric acid in the cold, a boiling heat is made use of by some to effect the combination. Other manufacturers oxyde the copper by exposing it to heat before they place it in the acid. Or dissolve the oxyd of copper at once in sulphuric acid.

Sometimes the sulphat of copper is contaminated with a mixture of the sulphat of iron (copperas.) This circumstance will make it unfit for most purposes. The presence of this last is ascertained by dissolving a portion of the suspected salt in water, and adding the infusion of galls to it; if there be any iron in the solution a black colour will be produced.

Sulphat of copper has a very strong, styptic, somewhat acidulous, and excessively nauseous taste. It is soluble in about four times its weight of water. When dried at a heat not exceeding that of boiling water, it loses, according to Proust, about 36 *per cent.* which is mere water, after which the residue, which is a white pulverulent mass, is again soluble and crystallizable, as at first. But if it is calcined with a strong white heat, the acid itself is expelled without undergoing decomposition, and at length there only remains black oxyd of copper, in the proportion of 32 *per cent.* of the original crystallized salt. Hence 100 parts of sulphat of copper consist, according to Proust, of

Copper	25.6	forming black oxyd	32
Oxygen	6.4		
		Sulphuric acid	32
		Water	36
			100

Bergmann's analysis of this salt nearly agrees with that of Proust in the proportion of copper (26 *per cent.*); but of the other ingredients he reckons 28 of water, and 46 of acid. [*Rees's Encyc. Art. Copper.*

Verdigris.—I know of no more authentic account than Chaptal's dissertation on the subject who has had more opportunities of information than any person else who has treated on this manufacture. I would premise, however, that I can see no reason why common blue vitriol precipitated by pearl ash, will not answer all the purposes of verdigris. They are both carbonats of copper. In the dying of hats, I am persuaded that much of the verdigris is wasted, and that blue vitriol would be an advantageous substitute; for blue vitriol and logwood give a blue, which though very fugitive on cotton, stands tolerably well when mixed with the black dye of the hatters.

Observations on the Manufacture of the Acetite of Copper or Verdigris, Verdet, &c.

The acetite of copper is one of the preparations of that metal most frequently used in the arts. It is not only one of the principal resources of painting, but upon many occasions is employed with great advantage in dying. Almost all the oxyds of copper obtained by the action of saline substances have a blue colour, more or less inclining to green; and almost all the neutral salts corrode the metal, and produce that oxyde which is called verdigris. It is sufficient to bring them into contact with the copper, or to immerse the metallic plates in a saline solution, and afterwards to expose them to the air to dry.

Those acids which oxydate the copper by their decomposition, produce an effect like that of neutral salts. The oxyde is of a soft blueish-green colour; their action is so speedy, that if the copper be exposed to the vapour of them for some minutes, its surface will be immediately oxydated. The oxygenated muriatic acid produces that effect as well as the vapour of the nitric acid, and even those of the sulphuric acid. A phenomenon which cannot escape the eye of an observer, is, that the oxydes of copper obtained by fire, are very different from those produced by the decomposition of acids on that metal. The colour of them is grey, instead of being green; and when the calcination is continued a long time at a violent heat, they may be concentrated to a red oxyde of a blood colour. This phenomenon was observed by Kunckle in his Chemical Laboratory.

Saline substances are not the only ones capable of oxydating copper green. All oils and fat matters produce the same effect. Even water, when left for a considerable time in copper vessels, causes an oxydation. But what will appear very extraordinary, is, that the greater part of these substances have no sensible effect upon cop-

per, except when cold. Those salts even which corrode that metal when left at rest in vessels, do not attack it in so sensible a manner when in a state of ebullition.

Of all the preparations of copper by oxydation, there is none more valuable than that made by vinegar. All the verdigris used in commerce is prepared by that acid, and it is at Montpellier in particular and in the neighbourhood, that the manufactories of it are established. In the Memoirs of the Academy of Paris for 1750 and 1753, may be seen a very exact description of the process then followed at Montpellier for making verdigris; but as that process has been much improved, and as at present the husks of grapes are employed instead of the stalks, a method far more economical, since wine is no longer used, the following account of the manner of manufacturing verdigris, as now practised, may be of utility to the public.

The first materials used for this purpose are copper and the husks or skins of grapes left after the last pressing. The copper employed was formerly all imported from Sweden; but at present it is brought from different foundries established at Saint Bel, Lyons, Avignon, Bedarieux, Montpellier, &c. It is in round plates half a line in thickness, and from twenty to twenty-five inches in diameter. Each plate at Montpellier is divided into twenty-five laminæ, forming almost all oblong squares of from four to six inches in length, three in breadth, and weighing about four ounces. They are beat separately with the hammer on an anvil to smooth their faces, and to give the copper the necessary consistence. Without this precaution it would exfoliate, and it would be more difficult to scrape the surface in order to detach the oxydated crust. Besides this, scales of pure metal would be taken off, which would hasten the consumption of the copper.

The husks of grapes, known at Montpellier under the

name of *racque*, were formerly thrown on the dung-hill after the poultry had picked out the small stones contained in them. At present they are preserved for making verdigris, and sold at the rate of from fifteen to twenty livres per *muid.* The preparation of them is as follows: After the vintage is finished, the husks are subjected to the press in order to extract all the wine with which they may be impregnated, and they are then put into vats, where they are pressed down with the feet to fill up all the vacuities and render the mass as compact as possible. The coverings of these vats are carefully fastened down, and they are preserved for use in a dry cool place.

These husks are not always of the same quality: when the grapes contain little of the saccharine matter, when the season has been rainy, the fermentation incomplete, or when the wine is not generous, the husks are attended with several faults. 1. They are difficult to be preserved, and there is great danger of their soon being spoilt. 2. They produce very little effect, cannot be easily heated, send forth very little of the acetous odour, and make the plates of copper sweat without shewing efflorescence on their surface. Independently of the nature of the grapes and the state of the wine, the quality of the husks varies also according as they have been expressed with more or less care. Husks which have not been much pressed, produce a far greater effect than those which have been dried. To explain their different effects, it will be sufficient to observe that their action is proportioned to the quantity of wine they retain, as it is that liquor alone which can pass to the state of vinegar. When the husks therefore are destined for a verdigris manufactory, care must be taken to express them only weakly, in order to preserve more of their acidifiable principle.

When a sufficient quantity of copper and of husks has been provided, nothing remains but to proceed to the ope-

rations, which are generally performed in cellars. They may be performed also on a ground floor if it be somewhat damp, if the temperature be subject to little variation, and if there be not too much light. The first operation is to make the husks ferment, which is called *avina.* For that purpose one of the vats is opened, and the husks are put into two others of equal size, taking care to expose them as little as possible to the air, and not to compress them. One vat full of husks ought to fill two, and to occupy a double space after this operation. In some manufactories the husks contained in a vat are distributed into twenty or twenty-five earthen vessels or jars called *oules*, and which are generally sixteen inches in height, fourteen in diameter at the belly, and about twelve at the mouth. When the husks have been put into these vessels, they are covered by putting the lid merely on the opening without pressing it down. The covers are of straw, and made for that purpose. In this state the husks soon heat; and this change may be known by thrusting the hand into them, and by the sour smell which they begin to exhale. The fermentation first takes place at the bottom of the vessel, and gradually ascending extends itself to the whole mass. It proceeds to 30 or 35 degrees of Reaumur.

At the end of three or four days the heat decreases, and at length ceases entirely; and as the manufacturers apprehend the loss of a portion of the vinegar by the natural effect of a heat too much prolonged, they take care after three days fermentation to remove the husks from the fermenting vessels, in order that they may sooner cool.

Those who employ vats remove them into jars, and those who use jars put them into others. Besides the loss of the acetous spirit, too great heat inclines the mass at the bottom of the vessel to become mouldy, which renders it unfit for making verdigris. Some manufactu-

rers, to increase the effect of the husks, form them into heaps, which they besprinkle with generous wine before they bring them to ferment.

The fermentation does not always take place at the same time, nor with the same energy. Sometimes it commences in twenty-four hours, and sometimes it has not begun at the end of three weeks. The heat sometimes will rise to such a height that the hand cannot be kept in the mass, and that the acetous odour is so strong that one can hardly approach the vessels; while at others the heat is hardly sensible, and soon vanishes. There are even instances of the husks becoming putrid and mouldy without turning acid. The fermentation is assisted and promoted by raising the heat of the place by means of chafing-dishes, by covering the vessels with cloths, by shutting the doors, and by airing the mass with more care. The differences in the fermentation depend, 1. On the temperature of the air: in summer the fermentation is speedier. 2. On the nature of the husks: those which arise from very saccharine grapes heat more easily. 3. On the volume of the mass: a larger mass ferments sooner, and with more strength, than a small one. 4. On the contact of the air: the best aired husks ferment best.

At the same time that the husks are made to ferment, a preliminary preparation called *desafouga* is given to the plates of copper which are used for the first time. This operation is not employed for those which have been already used, and consists in dissolving verdigris in water in an earthen vessel, and rubbing over each plate with a piece of coarse linen dipped in this solution. The plates are then immediately placed close to each other, and left in that manner to dry. Sometimes the plates are only laid on the top of the fermented husks, or placed under those which have been already used for causing the copper to oxydate. It has been observed, that when the ope-

ration called *desafouga* has not been employed, the plates grow black at the first operation, instead of becoming green.

When the plates are thus prepared, and the husks have been brought to ferment, the workmen try whether the latter are proper for the process, by placing under them a plate of copper, and leaving it buried there for twenty-four hours. If the plate of copper, after this period, is found covered with a smooth green crust, in such a manner that none of the metal appears, they are then thought fit for being disposed in layers with the copper. On the other hand, if drops of water are observed on the surface of the plates, the plates are said to *sweat*, and it is concluded that the heat of the husks has not sufficiently subsided. They consequently defer making another trial till the next day. When they are assured that the husks are in a proper state, they form them into layers in the following manner:

The plates are all put into a box, which, instead of having a bottom, is divided in the middle by a wooden grate. The plates disposed on this grate are so strongly heated by a chafing-dish placed under them, that the woman employed in this labour is sometimes obliged to take them up with a cloth, in order that she may not burn her hands. As soon as they have acquired that heat, they are put into the jars in layers with the husks. Each jar is then closed with a covering of straw, and left to oxydate. This period is called *coua*, to hatch. Thirty or forty pounds of copper, more or less according to the thickness of the plates, are put into each jar. At the end of ten, twelve, fifteen, or twenty days, the jar is opened; and if the husks are white, it is time to take out the plates. The crystals are then seen detached, and of a silky appearance on the surface. The husks are thrown back, and the plates are put in what is called *relai*. For that purpose

they are immediately deposited in a corner of the cellar on sticks ranged on the floor. They are placed in an upright position, one leaning against the other; and at the end of two or three days they are moistened, by taking them up in handfuls and immersing them in water in earthen pans. They are deposited quite wet in their former position, and left there for seven or eight days; after which they are once or twice immersed again. This immersion and drying are renewed six or eight times, every seven or eight days. As the plates formerly were put into wine, these immersions were called *one wine*, *two wines*, *three wines*, according to the number of times. By this process the plates swell up, the green is nourished, and a coat of verdigris is formed on all their surfaces, which may be easily detached by scraping them with a knife.

Each jar furnishes five or six pounds of verdigris at each operation. It is then called fresh verdigris, moist verdigris, &c. This verdigris is sold in that state by the manufacturers to people who dry it for foreign exportation. In this first state it is only a paste, which is carefully pounded in large wooden troughs, and then put into bags of white leather, a foot in height and ten inches in diameter. These bags are exposed to the air or the sun, and are left in that state till the verdigris has acquired the proper degree of dryness. By this operation it decreases about fifty per cent. more or less according to its primitive state. It is said to stand proof by the knife, when the point of that instrument pushed against a cake of verdigris through the skin cannot penetrate it.

The plates of copper which have been already used are again employed for the same operation, till they are almost completely consumed. Instead of heating them artificially, as above mentioned, they are sometimes exposed only to the sun. The same plates will serve sometimes for ten years, but they are often worn out in two or

three. This, however, depends on the quality of the copper. That which is extremely smooth, well beat, and very compact, is always most esteemed.

Formerly moist verdigris could not be sold till its quality had been previously ascertained; and for that purpose it was carried to a public ware-house, where it was sold after that point had been determined.

By comparing this process with that described by Montet, it will be found that the changes introduced are much in favour of the new. Formerly the workmen took the stalks of the grapes dried in the sun, and began by immersing them for eight days in *vinasse* (the residuum of the distillation of wine for making brandy). They then suffered the moisture to drain off through a basket, after which they put about four pounds into a jar, and poured over them three or four pints of wine. The stalks were made to imbibe a large portion of the wine, by stirring them strongly with the hand; the jar was then covered, and the stalks were suffered to ferment. The fermentation commenced sooner or later, according to the nature of the wine and the temperature of the air. But after it had once begun, the wine became turbid, and exhaled a strong odour of vinegar. At length the heat decreased, and the stalks were then taken out and the wine was drawn off. When the stalks were a little drained, they were disposed in layers with the plates of copper, and the operation was continued in the same manner as with the husks. When the plates were taken from the jars to be put in *relai*, instead of immersing them in pure water, as is done at present, they were moistened three or four times with sour wine, which was called giving them three or four wines.

It may be easily seen that there is a great saving in the process followed at present, since the manufacturers no longer use wine, which enhanced the price of the verdigris.

Some have condemned, in the new process, the practice of using the copper too soon; but this objection fell to the ground, when it was observed that the verdigris obtained was in proportion to the copper corroded; and what proves that this method is more advantageous, is, that all the manufacturers have abandoned the old method and adopted the new.* [4*th Phil. Mag*. 71.

Preparation of Crystallized Acetite of Copper: Crystalli veneris.

This is called in the colour shops distilled verdigris. Chaptal has given the process as follows:

Crystals of Venus were for a long time manufactured in Holland, but at present they are manufactured at Montpellier, with a degree of perfection which renders them preferable to those of any other country. The process most generally employed consists in dissolving verdigris in vinegar, and evaporating the solution to a pellicle to obtain the crystals. The vinegar used is nothing else than sour *vinasse* (spoilt wine) distilled. In every manufactory there is therefore an alembic, in which this weak kind of vinegar is continually distilled.

This distilled vinegar is put into a kettle, where it is boiled on the verdigris. After saturation the solution is left to clarify, and then poured into another kettle of copper, where it is evaporated to a pellicle. Sticks are then immersed into it, and by means of some pack-thread are tied to wooden bars which rest on the edge of the kettle. These sticks are about a foot long, and are split crosswise nearly two inches at the end, so that they open into four branches, kept at about the distance of an inch from each other by small pegs. The crystals adhere to these

* There are no large manufactories of verdigris at Montpellier; but each family makes a certain quantity, and the operations are in general performed by women.

sticks, and cover them entirely, forming themselves into groups or clusters, which present on all sides perfect rhombs of a very lively dark blue colour. Each cluster weighs from five to six pounds. These crystals, when broken, exhibit on their fracture a brilliant agreeable green, inclining a little to blue.

Three pounds of moist verdigris are necessary to make a pound of crystals. The indissolved residuum is rejected as useless. Analysis, however, having proved to me that a great deal of copper in a metallic state, or weakly oxydated, still exists in it, I disposed boards in the form of a stage around the manufactory of C. Durand, and, forming strata of about two inches in thickness with these remains, I soon saw them covered with an efflorescence of verdigris. I took care to moisten them from time to time with vinegar, to dissolve the verdigris as soon as a sufficiently strong efflorescence was formed, and they were again disposed in strata to proceed as before, in order that I might derive as much advantage from the residuum as I should find convenient.

There are some manufactories of the crystals of Venus where the verdigris is prepared by means of vinegar distilled according to the method followed at Grenoble, which is well understood. All the operations tend to the same end, which is the solution of the copper in the acetous acid; and the purity of the materials renders it certain that there will be no residuum or loss. But however simple may be the process for manufacturing crystallized verdigris, the high price at which it is sold makes it much to be wished that it could still be rendered more so. I made some experiments for that purpose; but at present I shall confine myself to a short view of my results. We must set out from the principle, that the acetous acid does not attack copper in the state of a metal, and that it cannot effect a solution of it but when re-

duced to an oxyd. The question then will be to discover the means of oxydating it in an economical manner.

1st, I exposed the plates of copper to the gazeous emanations of the oxygenated muriatic acid in large glass receivers, connected together in the manner of adoptors, to which I fitted a retort from which the acid was disengaged.

2d, I took a large earthen jar of Provence, well glazed, capable of containing two hundred (French) pints of water, buried it one half in a stratum of very warm dung in full decomposition, and having put some manganese in the bottom of it, and adapted to it a straight glass tube, which reached from the mouth to the bottom, I filled the jar with plates of copper slightly rolled, in order that they might not touch each other but in some points. I then made to pass into the bottom of the jar, by means of the tube, the necessary quantity of the muriatic acid, and immediately closed the upper aperture with a luted covering. Two days after these plates were entirely crusted over with a greenish oxyd, which detached itself in dust and in scales: I separated of it two pounds ten ounces. This oxyd, less lively than that of the common verdigris, is soluble in vinegar: and this method may then be employed, with some advantage, to form the acetat of copper; but it cannot supply the place of the acetous verdigris either in painting or dyeing.

3d, I formed sulphat of copper by pouring, upon plates of copper brought to a red heat in a crucible, about a third in weight of pounded sulphur. This sulphur, exceedingly friable, pulverised and exposed to a pretty violent heat for four or five hours, left a grey powder, easily attacked by the acetous acid. That which I digested at a heat above a gentle temperature, gave, by evaporation, a considerable quantity of very blue and beautiful crystals of acetat of copper, and a stratum of true sulphat of copper of a pale blue and without crystals.

4th, I saturated distilled acetous acid with oxygenated muriatic acid gas. This acid, digested cold on the copper, dissolved it in part; but it formed a beautiful micaceous scaly white, which had no relation with the acetat. Copper exposed to the vapour of this acetous acid, saturated with oxygenated muriatic acid gas, becomes covered with very brilliant small crystals of a bright-blue colour, some of which are transparent and white. These crystals presented long square pyramids, effloresced in the air, and had none of the characters of the acetat of copper.

5th, The acetous acid, distilled several times on the oxyd of manganese, attacks copper and dissolves it, but too weakly and in too small quantity for me to recommend this method.

6th, The acetite of lead poured upon a solution of the sulphat of copper immediately produces a decomposition from which there results sulphat of lead, which precipitates itself in a little time; and acetat of copper, which re-remains in solution. By decanting the latter, and evaporating it to a pellicle in a copper kettle, you will obtain beautiful crystals of Venus. If you wash well the sulphat of lead, and prepare it to be employed in painting, as white lead, this last process may become very advantageous.

Crystallized verdigris is in great request for painting and varnishing, to which it supplies lively and durable colours. Chemists obtain from it by distillation that acid, the smell of which is very penetrating, called *radical vinegar*, and also *acetite acid.*—4 *Philos. Mag.* 171.

Preparation of acetic acid or radical vinegar. This used to be prepared in large quantities for sale, as an antiseptic, and aromatic, as well as a cephalic medicine, (to be smelt at) by Mr. Henry, father to Dr. William Henry, of Manchester. I do not know, therefore, that any bet-

ter account can be given of its preparation than Dr. Henry's own. For my own part, I strongly suspect that in the large way, common strong vinegar is saturated with whiting: filtered, reduced to a dry mass, and distilled with vitriolic acid. The retort will contain sulphat of lime. The vinegar must be re-distilled with a moderate heat.

"When this salt, acetite of potass is distilled, with half its weight of sulphuric acid, the vegetable acid is expelled in a very concentrated form, mixed with sulphurous acid. Digestion with a small portion of manganese, and subsequent distillation, affords it pure. It may be obtained, also, by distilling equal parts of acetate of lead and sulphat of copper. Or

The crystallized acetate of copper, contained in a glass retort, which may be nearly filled with the salt, may be submitted to distillation in a sand-heat. The acid that comes over has a green colour, and requires to be rectified by a second distillation. Its specific gravity then varies from 1056 to 1080. If the products be reserved in separate portions, it has been observed by M. M. Derosne, that those which are obtained towards the close, though specifically lighter than the earlier ones, are still more powerfully acid, assuming, as the test of their strength, the quantity of alkali which they are capable of saturating. The last products, it was found also, when submitted to distillation, yield a liquid which has even less specific gravity than water. This liquid may be obtained, in a still more perfect state, by saturating the latter portions of acetic acid with caustic and solid potash; the acetate of potash precipitates; and a fluid swims above it, which may be rectified by distillation at a gentle heat. It is perfectly limpid; has a penetrating taste; is lighter than alcohol; evaporates rapidly with the production of cold when poured upon the hand; and is highly inflam-

mable. It does not redden litmus. Excepting that it is miscible, in any proportion, with water, it has all the qualities of ether, and like that fluid has the power of decomposing the nitromuriate of gold. M. M. Derosne have proposed for it the name of *pyro-acetic ether*. Its production, they observe, is confined to the latter stages in the distillation of acetate of copper, and is owing, they suppose, not to any modification of alcohol, but to changes in the arrangement of the elements of the salt.

These observations are confirmed by the subsequent ones of M. Mollerat. Examining two portions of acetic acid, which had precisely the same specific gravity (*viz.* 1063), he found that the one contained 87 *per cent.* of real acid, and the other only 41. The first he is disposed to consider as the strongest acetic acid that can be procured. It may be distilled at a very moderate heat with great rapidity, and without entering into ebullition. To this acid, having the specific gravity 1063 (and of which 100 grains required for saturation 250 of sub-carbonate of soda), he gradually added water, and found, though water is lighter than the acid, yet that the density of the mixture increased till it became 1079. From this point, the additions of water occasioned a regular diminution of specific gravity. Mr. Chenevix has since observed the same anomally, in the acid produced from acetate of silver.

Acetic acid, thus prepared, has several remarkable properties. Its smell is extremely pungent, and it raises a blister when applied to the skin for a sufficient length of time. When heated in a silver spoon over a lamp, its vapour may be set on fire. At the temperature of about 38° Fahrenheit it becomes solid and shoots into beautiful crystals, which again liquefy at 40°. It appears not to be easily destructible by heat; for Mr. Chenevix transmitted it five times through a red-hot porcelain tube, with the effect of only a partial decomposition."

2 *Hen. Ch.* 220.

Scheele's Green: Arseniat of Copper. Dissolve in 45 parts of boiling water, 2 pounds by weight of pounded blue vitriol or sulphat of copper. In 10 parts by weight of boiling water dissolve 2 parts of potash and 1 1-2 part of white arsenic, boiling it, till the latter is dissolved. Then make up the liquor 45 parts by adding boiling water (taking a wine pint as 16 ounces). Add the first solution while hot, gradually to the last. A precipitate will fall down of a fine green colour, which is arseniat of copper. Wash it well and dry it. It is a good pigment both as an oil and water colour.

If you want it diluted, add to your solution of blue vitriol one part or more, by weight of alum, in which case you must encrease your potash one half part for each part of alum.

This is the common green used by the paper stainers.

Brunswick green. This is said to be made by stratifying shavings of copper with ground argol or tartar made into a paste, which I have no doubt would produce a good colour. But M. Kastelyn's receipt is as follows: Dissolve three parts by weight of sal ammoniac in water: put into a close or covered vessel two parts by weight of copper shavings, sprinkle them from time to time with the solution of sal ammoniac. The green colour produced will weigh six parts.

Verditer, is made in three or four ways. 1st, By precipitating copper from a solution of blue vitriol or sulphat of copper, by means of a clear solution of pearl or potash. About half a part of potash by weight, or 3 fourths of a part of pearl ash, will throw down the copper of one part of blue vitriol. This will form a carbonat of copper, or an imitation of verdigris equally good in all particulars.

2dly, By precipitating a solution of blue vitriol with whiting, in which case, the copper thrown down is dilut-

ed and enfeebled in colour by the addition of sulphat of lime, formed by the union of the lime of the whiting to the sulphuric acid of the blue vitriol. This is what is called Sanders' blue: a corruption I presume of *cendres blues*.

3dly, When the refiners dissolve together in aqua fortis a mixture of copper and silver, they separate the silver by adding a solution of common salt; the acid of common salt unites with the silver, and the alkali of common salt unites with that portion of the aqua fortis which held the silver in solution. The liquor now contains nitrat of copper and nitrat of soda. The copper may be thrown down, either by a solution of pearl or potash, or by whiting. In this latter case, the whiting does not mix with and contaminate the colour of the precipitate, as the nitrat of lime is soluble in water.

These precipitates when washed, form the various shades of green and blue Verditer, used by the paper stainers.

In all these cases, the precipitate is a carbonat of copper: different shades may also be procured, by using pure lime, and pure or caustic potash. (Soap boiler's Ley.)

Mr Hatchett's brown prussiat of copper.

On the utility of Prussiat of Copper as a pigment. By Charles Hatchett, Esq. F. R. S.

The accidental discovery made by Diesbach of the pigment called Berlin or Prussian blue, about the year 1710, and which afterwards was published by Woodward in the Philosophical Transactions for 1724, was soon adopted by artists and manufacturers, so that in a short time the great utility of this colour was completely established: it is therefore remarkable, that but little attention has been subsequently paid to the colorific properties of the other metallic prussiates.

The experiments made by Mr. Brown with the prussic lixivium on various metallic solutions do not merit particular attention, as the results evidently show that a very large proportion of the alkali remained unsaturated with prussic acid, and thus the effects appeared different when the lixivium was prepared with blood or with muscle.

Bergman has, however, more accurately observed the properties of metallic precipitates, (Opuscula, tom. ii. p. 385), and especially notices the various colours of the prussiates; but neither he nor any other chemist, as far as I am acquainted, has pointed out to artists the utility of prussiat of copper as a pigment. During some late experiments, I was much struck with the beauty of this precipitate, and was therefore induced to make several trials of it as a paint: the results exceeded my most sanguine expectations. I afterwards prepared a large quantity, which at my request several gentlemen (particularly B. West, Esq. P. R. A., John Trumbull, Esq., and Sir H. C. Englefield,) were so obliging as to try in oil, and in water; and I have had the satisfaction to learn, that in beauty and intensity it surpasses every brown paint now in use, with the additional advantage, that, by reason of its purple tint, it forms with white various shades of bloom or lilac colour, which do not appear liable to fade like those which are formed by means of lake.

The prussiates obtained from acetite, sulphate, nitrate, and muriate of copper, are all very beautiful; but the finest and deepest colour is afforded by the muriate. I have found also that prussiate of lime can be better depended upon for this purpose than prussiate of potash. The best mode, therefore, of forming this pigment, is to take green muriate of copper, diluted with about ten parts of distilled or rain water, and to pour in prussiate of lime until the whole is precipitated: the prussiate of copper is then to be well washed with cold water on the filter, and to be dried without heat.—14 *Phil. Mag.* 359.

This colour seems to me to have been first pointed out by Dr. Bancroft in page 217 of his experimental researches on permanent colours, first edition.

Of the Alloys of Copper. Brass. Orichalchum. The orichalchum of the ancients, was of three kinds: the mountain copper mentioned by Hesiod. The Corinthian brass, a mixture of various metals from the melting together of the statues, at the taking of Corinth. Lastly, Brass, made by fusing copper with cadmia or calamine. That, latterly, the orichalchum of the ancients was brass, is sufficiently made out by the Bishop of Landaff in his treatise on orichalchum in the second volume of the Manchester Transactions, and in his Essays, vol. 4. His account of the modern process for making brass is as follows:

The method of making ordinary brass I will now describe.

Copper in thin plates, or, which is better, copper reduced (by being poured, when melted, into water) into grains of the size of large shot is mixed with calamine and charcoal, both in powder, and exposed in a melting pot for several hours to a fire not quite strong enough to melt the copper, but sufficient for uniting the metallic earth of the calamine to the phlogiston of the coal; this union forms a metallic substance, which penetrates the copper contiguous to it, changing its colour from red to yellow, and augmenting its weight in a great proportion. The greater the surface of a definite weight of copper, the more space has the metallic vapour of the calamine to attach itself to; and this is the reason that the copper is granulated, and that it is kept from melting and running into a mass at the bottom of the vessel, till near the end of the operation, when the heat is increased for that purpose.

The German brass-makers, in the time of *Erckern*, used to mix 64 pounds of small pieces of copper with 46 pounds of calamine and charcoal, and from this mixture

they generally obtained 90 pounds of brass.* Cramer recommends 3 parts of powdered calamine to be mixed with an equal weight of charcoal dust and two parts of copper, and says, that the brass obtained by the process exceeds the weight of the copper by a fourth, or even a third part of its weight.† At most of our English brass-works they use 45 pounds of copper to 60 pounds of calamine for making ingot brass, and they seldom obtain less than sixty or more than seventy pounds of brass; at Holywell they reckon the medium product to be 68: and hence a ton of copper, by this operation, becomes rather more than a ton and an half of brass. This is a larger increase of weight in the copper, than is observed in any of the foreign manufactories that I have ever read of, and it may be attributed to two causes, to the superior excellence of our calamine, and to our using *granulated* copper. Postlethwayte, in his Commercial Dictionary, attributes the difference in the increase of weight acquired by the brass to the different natures of the coppers which are used, "there is an increase of 48 or 50 pounds in an hundred, if copper of Hungary or Sweden be used; that of Norway yields but 38, and that of Italy but 20." When they make brass which is to be cast into plates, from which pans and kettles are to be made, and wire is to be drawn, they use calamine of the finest sort, and in a greater proportion than when common brass is made, generally 56 pounds of calamine to 34 of copper. Old brass which has been frequently exposed to the action of fire, when mixed with the copper and calamine in the making of brass, renders the brass far more ductile and fitter for the making of fine wire than it would be without it; but the German brass, particularly that made at *Nuremberg*,

* Fleta Minor, by Sir J. Pettus, P. 286. Newman gives the same proportions, P. 65.

† Cram. Ars Doc. Vol. II. p. 246.

is, when drawn into wire, said to be preferable to any made in England for musical instruments. If this preference be real, it will cease to exist as soon as any ingenious man shall undertake to examine the subject, for our materials for making brass are as good as any in the world. The quantity of charcoal which is used, is not the same at all works, it is generally about a fourth part of the weight of the calamine; an excess of charcoal can be attended with no other inconvenience than that of uselessly filling up the pots in which the brass is made; but powdered pitcoal, which is used at some works in conjunction with, or in the place of charcoal, greatly injures the malleability of the brass. As to black jack, the other ore of zinc, it is not so commonly used as calamine for the making of brass. The manufacturers have been somewhat capricious in their sentiments concerning it, some have prefered it to calamine, and others have wholly neglected it; and the same persons at different times have made great use of it, or entirely laid it aside. There must have been some uncertainty in the produce or goodness of brass made by this mineral, to have occasioned such different opinions concerning it, and this uncertainty may have proceeded either from the variable qualities of the mineral itself, or from the unskilfulness of the operators in calcining, &c. a mineral to which they had not been much accustomed. Several ship loads of it were sent a few years ago from Cornwall to Bristol, at the price of 40 shillings down to a moidore a ton.* Upon the whole, however, experience has not brought it into reputation at Bristol. [4 *Wats. Ess.* 48—54.

Dr. Aikins' article which is fuller, is as follows.

This very important alloy is a mixture of copper and zinc in various proportions, so intimately united as to form a homogeneous malleable yellow metal, appli-

* Miner. Cornu. p. 47.

cable to a vast variety of purposes and capable of being wrought with the greatest facility.

It is not easy to obtain a perfect union of zinc and copper by mere fusion in open vessels, for at a heat less than is required to melt the copper, the zinc readily takes fire and much of it burns off before it has time to mix with the other metals, so that the proportion of zinc is constantly lessening by volatilization. Even after both metals are fused, the zinc continues to burn off in uncovered vessels, and at last scarcely any thing but copper would be left. In order therefore to combine copper most intimately with zinc, and yet to preserve its malleability, the ingenious process of *cementation* has been resorted to in the manufacture of brass, which is performed by heating in a covered pot alternate layers of copper in small pieces, with zinc ore and charcoal, and continuing the fire till the copper is thoroughly impregnated with the zinc.

Zinc being a volatile metal can only be procured from its ores by sublimation; the process for obtaining it (which will be described more at length under that article) being to heat strongly a mixture of its ore with charcoal in a vessel closed on all sides, except where it admits a tube, the lower end of which dips in water: as soon as the charcoal reduces the oxyd, the metal rises in vapour through the tube and condenses in the water below. A similar reduction takes place in brass-making, only the vapour of the zinc instead of being conveyed out of the crucible in which it is formed, unites with the copper enclosed in the same vessel, and the whole melts down into brass. A less heat is required in brass-making than that which fuses copper, the zinc being able to penetrate the copper when thoroughly red hot, and melting it down as soon as it becomes brass.

Brass is manufactured in many countries, but no where more extensively and better than in England, where

both the materials are in great abundance. The ores of zinc are several species of *calamine* and of *blende*, called by the miners *Black-Jack*, which are found abundantly in Devonshire, Derbyshire, and North-Wales, generally accompanying lead ores. These are chiefly oxyds or carbonated oxyds of zinc, and require a previous calcination before they are fit for brass-making. Blende is a sulphuret.

At Holywell, in Flintshire, the calamine which is received raw from the mines in the neighbourhood, is first pounded in a stamping mill, and then washed and sifted in order to separate the lead, with which it is largely admixed. It is then calcined on a broad shallow brick hearth, over an oven heated to redness, and frequently stirred for some hours. In some places a conical pile is composed of horizontal layers of calamine alternating with layers of charcoal, the whole resting on a layer of wood in large pieces, with sufficient intervals for the draught of air. It is then kindled, and the stack continues to burn till the calamine is thoroughly calcined. The calamine thus prepared is then ground in a mill, and at the same time mixed with about a third or a fourth part of charcoal, and is then ready for the brass-furnace. In some places pit-coal is ground with the calamine instead of charcoal, but this is found to injure the malleability of the brass obtained.

The brass-furnace* has the form of the frustum of a hollow cone, or a cone with the apex cut off horizontally. At the bottom of the furnace is a circular grate or perforated iron plate, coated with clay and horse-dung, to defend it from the action of the fire. The crucibles stand upon the circular plate, forming a circular row with one in the middle. The fuel, which in England is coal, is thrown round the crucibles, being let down through the

* Keir in a note to the article *Brass* in Macquer's Chem. Dict.

upper opening or smaller end of the cone: over this opening is a perforated cover made of fire-bricks and clay, and kept together with bars of iron so as to fit closely. This cover serves to regulate the heat in the following manner: the draught of air is formed through an under-ground vault to the ash-hole, thence through the grate and round the crucibles, and through the smaller upper opening into an area where the workmen stand, which is covered by a large dome and a chimney to convey the smoke into the outer air. When the draught is the strongest, and the heat is required of the greatest intensity, the cover is entirely removed and the flame then draws through the upper opening of the furnace to a considerable height into the outer brick dome; when the heat is to be lessened the cover is put on, which intercepts more or less of the draught from the furnace, as more or fewer of the holes of the cover are left unstopped.

The crucibles are charged with the mixed calamine and charcoal, together with copper clippings and refuse bits of various kinds, and sometimes brass clippings also, most of which are previously melted and run into a small sunk cistern of water through a kind of cullender, which divides the metal into globules, like shot. Powdered charcoal is put over all, and the crucibles are then covered and luted up with a mixture of clay or loam and horse-dung.

The time required for heating the crucibles and compleating the process varies considerably in different works, being determined by custom, by the quantity of materials, the size of the crucibles, and especially the nature of the calamine. In the great way from ten to twenty-four hours are required. At Holywell, in Flintshire, about twenty-four hours are taken.

During the process, and especially towards the latter end, part of the reduced zinc which escapes absorption by

the copper, finds its way in vapour through the luting of the crucible-lids, and burns around them with the beautiful blue flame and dense white smoke peculiar to this metal. Of course, this is so much wasted.

The heat required for brass-making is somewhat less than what would be necessary to melt large masses of copper, brass being the more fusible of the two, and, as it should seem, the vapour of zinc being able to penetrate copper as soon as it is softened by a full red heat. When the brass is judged to be complete, and the saturation of the copper with zinc to be as high as possible, the heat is increased to melt the whole down into one clean mass at the bottom, the crucibles are taken out and the metal poured into moulds. At Holywell, out of the six crucibles used to one furnace, the quantity of brass obtained is about as much as would fill one of them. This makes in subsequent manufacture a single large plate, which is manufactured in the same way as copper plate. Or, more accurately, from forty pounds of copper and sixty pounds of calamine, about sixty pounds of brass are obtained, besides the loss of a good deal of zinc by the unavoidable escape of much of it in form of vapour through the pores of the lute or the crucible-covers.

The above is the usual process of brass-making in this country, and is essentially the same wherever this alloy is manufactured; but with some variation as to the choice of ingredients, their proportions, the time of fusion, the shape of the furnace and other smaller circumstances.

At Goslar, in Saxony, where brass is largely made, the zinc is furnished not by a native calamine, but the *cadmia* or sublimed oxyd of zinc, which is collected for this purpose in a particular part of the chimnies of the reverberatory furnaces in which the Saxon lead ores and blendes are roasted.

A great variety obtains in the respective proportions of

the ingredients. According to Swedenborg* they are, in Goslar, 30 parts of copper, 40 to 45 cf cadmia, and twice the volume of charcoal; at Paris, and in many of the French manufactories, they are, 35 of copper, 35 of old brass, 40 of calamine, and 20 to 25 of charcoal; in Sweden, 30 of copper, 20 to 30 of old brass, and 46 of calamine, with charcoal sufficient; or, 40 of copper, 30 of old brass, and 60 of calamine; and in England, generally about 40 of copper and 60 of calamine. The product of brass varies also, but it seems to be in few places so great as in some of the English works, where, as already mentioned, 40 pounds of copper become in the process 60 pounds of brass. This superior quantity is ascribed partly to the goodness of the calamine and partly to the smallness to which the copper is previously reduced by being poured melted into cold water, and thus affording a great surface of metal to the action of the zinc vapour.

At Stolberg,† near Aix-la-Chapelle, where brass is very largely manufactured, the furnaces are cylindrical, and each contains eight crucibles arranged in two tiers of four each. These crucibles are fifteen inches high, twelve inches deep, and eight or nine inches wide. The proportions of ingredients are 40 lbs. of copper, 65 lbs. of calamine, and double its volume of charcoal. After the fire has been kept up for twelve hours, the crucibles are uncovered, and a workman takes off with an iron trowel all the scum and charcoal which swim upon the liquid metal, and which is called *arkest*. When examined with a glass, this is found to consist of calamine and copper particles, cohering together but not completely united. The brass resulting from this first process is coarse, brittle, and unequal in texture, and requires a second fusion before it

* Macquer's Dictionary. † Repertory, vol. xiv.

is fit for use. For this purpose the same crucibles are again employed and are filled, first with three handfuls of the mixture of calamine and charcoal, over which are put two or three pounds of the impure brass broken in pieces, then more calamine and charcoal, with a lump of the *arkest*, and over all, calamine and charcoal powder. The crucible is then strongly heated for two hours, after which the brass is fit to be cast into plates, which is done here in the following manner.

A mould is formed of two blocks of granite, five feet long, three and a half broad, and eight inches thick. They are placed one above the other, the upper one being only moveable, and furnished with a tackle and pullies for that purpose, and before casting, the surface is smeared with cow-dung. To give the plate the requisite thickness, hoops of iron of different dimensions are adapted to the under stone, so as to confine a determinate quantity of melted metal. The stones are then gently inclined and the melted brass let in between them. These plates are afterwards laminated: some of them are cut into slips by strong shears, for the further purpose of being drawn into wire, and otherwise manufactured in various ways.

A single process, where the fire is kept up long enough and the materials are good, is certainly sufficient to make good malleable brass, but it is probable that the excellence and beauty of the article are improved by making it undergo a second cementation with fresh calamine and charcoal.

In the laboratory brass may be made very well in the small way in a much shorter time. Put into a crucible a mixture of calamine and charcoal, bury it in the requisite proportion of copper shot, cover the whole with charcoal powder, lute on a cover to the crucible, and heat slowly in a wind-furnace for half an hour, till the zinc begins to burn off in a blue flame round the top of the crucible,

then raise the fire and heat briskly for half an hour longer.

This process of cementation is also neatly shewn by the following management, as given by Cramer. Put the mixture of calamine and charcoal into a crucible, cover it with a thin layer of clay, over which when dry lay a thin plate of copper, cover the whole with fine charcoal powder, and lute on a cover to the crucible. Apply heat gradually, and the vapour of the reduced zinc will rise through the floor of clay, penetrate the red-hot copper plate above it, and gradually convert it into brass, which at the end of the operation will be found lying melted on the stratum of clay. The increase of weight gained by the copper in this operation will afford a good practical test of the goodness of the calamine, and its fitness for brass-making in the great way.

The most important properties of brass compared with copper are the following: the colour of brass is much brighter, and more approaching to that of gold; it is more fusible than copper; less subject to rust and to be acted on by the vast variety of substances which corrode copper with so much ease; and it is equally malleable when cold, and more extensible than either copper or iron, and hence is well fitted for fine wire. Brass however is only malleable when cold. Hammering is found to give a magnetic property to brass, perhaps however only arising from the minute particles of iron beaten off the hammer during the process and forced into the surface of the brass, but this circumstance makes it necessary to employ unhammered brass for compass-boxes and similar apparatus.*

The expansion of brass has been very accurately determined, as this metal is most commonly used for mathematical and astronomical instruments, where the ut-

* The brass contains iron. T. C.

most precision is required. Mr. Smeaton found that 12 inches in length of cast brass, at 32°, expanded by 180 degrees of heat (or the interval from freezing to boiling water) 225 ten thousandth parts of an inch. Brass wire under the same circumstances expanded 232 parts; an alloy of 16 of brass with 1 of tin expanded 229 parts. The expansion of hammered copper is only 204 such parts, but that of zinc is 253, so that brass holds a middle place, in this respect, between its two component metals.

Most of the zinc readily burns off from brass when kept melted in a strong heat with free access of air. When the heat is equal to that of melted copper, the zinc takes fire and slowly burns away. At last little else but copper remains, but still united with a small portion of zinc, which no further continuance of the fire will entirely separate.

Some kinds of very fine brass are said not be made by cementation in the way already described, but by a more speedy and direct union of copper and zinc, care being taken to prevent the access of air to the materials while in fusion. Very fine brass may also be made by mixing together the oxyds of copper and zinc, and reducing them with a carbonaceous flux. This idea is ingenious, and from the intimate mixture of the two metals which it promises, it deserves to be further pursued. M. Sage, gives the following experiment to this purpose. Mix together 50 grains of the oxyd of copper, remaining after the distillation of verdigris (which is very pure) with 100 grains of lapis calaminaris, 400 grains of black flux, and 30 grains of charcoal powder; melt the mixture in a crucible till the blue flame is seen no longer round the lid of the crucible, and when cold a fine button of brass is found beneath the scoria, weighing a sixth more than the copper alone, obtainable from its oxyd in the same way but without the calamine. This brass has a very fine colour like gold.

On this experiment M. Sage observes that there appears to be a point of mutual saturation between the two metals, which is when the copper retains one-sixth of zinc, and this portion it will retain however long it is heated, provided the surface of the melted metal be covered to protect the zinc from the action of the air; but if the brass contains a greater proportion of zinc, precisely this excess will escape, even in covered vessels, and will burn when it comes out to the air. The same chemist also observes that the colour is the finest at the above proportion. These experiments seem to require further confirmation; but at present we may reckon that to be the most perfect brass which is composed o about 14.28 per cent. of zinc and 85.7 of copper, and which is not liable to any alteration in its constituent parts by successive or long continued fusions, provided the access of air be prevented.

The *analysis* of brass has been attempted in various ways, and several processes have been given of different merit.

Brass may be to a certain degree analysed by simply being kept in fusion at a high heat with free access of air. The zinc readily burns, and by far the greater part of it escapes, and when the blue flame of the metal ceases the analysis is supposed to be complete, the loss of weight on the remaining metal indicating the quantity of zinc. But this is inaccurate from two causes; first, that a portion of zinc always remains in the copper however long the heat be continued, and secondly that part of the copper oxydates in the process, and thereby gains an increase of weight. Both these circumstances therefore contribute to indicate a smaller proportion of zinc than is really the case.

A simple solution of brass in the sulphuric acid and subsequent crystallization has also been recommended, on the idea that the crystals of sulphat of zinc could readi-

ly be obtained separate from those of the sulphat of copper. But though this separation takes place to a considerable degree it is not complete, for at the last the crystals of each salt are somewhat alloyed with the other, and the trouble of picking out the crystals when very small is extreme.

M. Dize* proposes the following methods. 1. Dissolve the brass in nitric acid, which takes up the copper and zinc and leaves any tin with which it is often alloyed. Decompose the clear nitrated solution by potash, redissolve the precipitate in sulphuric acid, and add a piece of clean bright iron to the solution, previously diluted with six times as much water. The copper is by this means precipitated in a metallic state, and the solution now holds sulphat of iron and sulphat of zinc. Add gallic acid, which will slowly separate the iron and leave the zinc. Lastly, decompose the sulphat of zinc by a carbonated alkali, and estimate the quantity of zinc contained in the carbonated oxyd of zinc thus obtained, by proportions which will be presently mentioned. The above method is useful, but the separation of the iron by the acid of galls is excessively tedious.

2. Dissolve the brass in nitric acid. Dilute with six parts of water, and immerse in the solution a cylinder of bright clean lead. The copper speedily separates in the metallic form round the lead, which last takes its place in the solution. As this process advances, the liquor loses its blue colour, and when all the copper is separated it is slightly yellow. To be certain that no copper remains in the solution, add a fresh clean piece of lead and boil for some time. The liquor now contains nitrat of lead and nitrat of zinc. Sulphuric acid will now precipitate the

* Jour. de Phys. tom. 48.

lead in the form of an insoluble sulphat, and the nitrated zinc may then be decomposed by a carbonated alkali.

On this precipitation however there are several things to be observed. Copper, as Vauquelin remarks,* when dissolving in nitric acid absorbs nearly $\frac{40}{100}$ of its weight of oxygen, but lead under the same circumstance absorbs only $\frac{16}{100}$. Hence one hundred parts of copper dissolved in nitric acid would require for their disoxygenation (a process which takes place whenever a metallic oxyd in solution is precipitated by the immersion of another metal in its metallic state) full 250 parts of lead, which last is of course oxydated in proportion as the copper is precipitated in the metallic form. But this large quantity of oxyd of lead cannot be held in solution by the nitric acid, except this is largely in excess, and this explains the reason of the appearance of a portion of oxyd of lead (as M. Dize has observed) which forms at the latter end of the process and mixes with the newly precipitated metallic copper, so as to require a subsequent operation to separate them. Nor will an excess of nitric acid ensure the purity of the precipitated copper, for it happens here, as is now found to take place in very many of the reguline metallic precipitates, that the newly-separated metal is not pure, but largely alloyed with the metal added as a precipitant. Therefore the loose flocculent metal which forms around the piece of lead is not pure copper, though it has a perfect cupreous appearance, but is copper largely alloyed with lead. Vauquelin found that if 50 grains of pure copper are dissolved in an excess of nitric acid, and then entirely precipitated by metallic lead, of which about 220 grains are required, the cupreous precipitate now weighs 138 grains instead of the original 50, and therefore is not pure copper but an alloy of 50 parts of copper with

* An. Chim. tom. 28.

88 parts of lead. This method therefore of analysing brass cannot be depended on, unless the cupreous precipitate be afterwards separately treated to separate the lead, which would render the analysis very complicated.

The following methods are given by Vauquelin.

3. Dissolve a known weight of brass in nitric acid; put it into a well closed bottle and add caustic potash to excess, so that there shall be a very sensible alkaline taste in the liquor, shake the mixture well, and keep it some time in digestion. By this process the oxyds of copper and zinc are first both precipitated by the alkali, and afterwards the zinc alone redissolved in the excess of potash, so that the clear solution is oxyd of zinc in potash, and the sediment left undissolved is the oxyd of copper. This oxyd is brown and nearly of the colour of metallic copper, but when thoroughly washed and gently dried, it only contains 65 per cent. of the metal. If a previous assay has shewn that the specimen of brass contained only copper and zinc, when the weight of the former is known, that of the other may readily be inferred; or else, the alkaline solution of zinc may be supersaturated with sulphuric acid, so as first to precipitate and afterwards to redissolve the metal, when the sulphuric solution may be decomposed by a carbonated alkali. A very trifling quantity of copper passes into the alkaline solution of zinc, occasioned by the action of a small quantity of ammonia, generated by the nitrated metals when caustic alkali is added to them. If necessary this might be again separated by a heat cautiously kept below boiling, which would expel the ammonia, the cause of this error, but if brought fully to boil some of the zinc would separate from the alkali and cause a much greater error than before.

4. Dissolve brass in sulphuric acid, dilute with twenty times as much water, and immerse a stick of zinc exact-

ly weighed. The copper soon completely precipitates in the metallic form, and requires only to be well washed and weighed. The solution now contains only the zinc of the brass, together with the zinc lost from the piece immersed to precipitate the copper. By weighing the remainder of the stick of zinc, and precipitating the whole by carbonated potash or soda, an easy calculation will determine how much of the oxyd of zinc is derived from the zinc contained at first in the brass. Or, more simply, this may be inferred from the copper obtained, and the quantity of brass originally employed.

It remains on the subject of analysis to give the constituent parts of carbonat of zinc. M. Dize dissolved 100 parts of zinc in nitric acid, precipitated it by carbonated soda, and this product well washed and *dried* now weighed 180 parts. Hence 100 parts of carbonat of zinc thus prepared would indicate 55.5 of metallic zinc.

On the other hand Vauquelin found that carbonat of zinc obtained from the sulphat by carbonated potash, well washed, and calcined in a crucible to expel all the carbonic acid, contained 69 per cent. of metallic zinc. Hence the carbonat obtained by Dize must have been dried at a low temperature, probably that of boiling water, and from either of the above data the proportion of zinc may be estimated; or else the carbonated oxyd may be mixed with about a fourth of charcoal and strongly heated in an earthen retort with the beak dipping in water, by which the zinc will be reduced and will rise into the neck of the retort, or partly fall into the water beyond.

Analysis shews a vast variety in the proportions of the different species of brass used in commerce. In general the extremes of the highest and lowest proportions of zinc are from 12 to 25 per cent. of the brass. Even with so much as 25 per cent. of zinc, brass, if well manufactured,

is perfectly malleable, though zinc itself scarcely yields to the hammer. M. Dize analized a specimen of remarkably fine brass made at Geneva, for the purpose of escapement wheels and the nicer parts of watch-making, the perfect bars of which bear a very high price. This metal unites great beauty of colour to a very superior degree of ductility. It was found to consist of 75 of copper with 25 of zinc, and probably too the copper was Swedish or some of the finer sorts. The common brass of Paris seems to contain about 13 per cent. of zinc, the English probably more.

The uses of brass are too numerous to be mentioned. It is applicable to an infinite variety of purposes, is easily wrought by casting and hammering, and by the lathe, its wire is eminently useful, and it takes a high and very beautiful polish. The appearance of brass is given to other metals by washing them with a yellow lacquer or VARNISH, a substitution often very much to the detriment of the manufactured article. 1 *Aikin*, 166.

In 1781 a patent was granted to Mr. James Emerson for his invention of making brass of copper and zinc, (spiauter, spelter as the Germans call this semi-metal).

The patentee directs the spelter to be melted in an iron boiler, then passed through a perforated ladle, and placed over a vessel containing water, by which means the zinc will be granulated. Fifty-four pounds of granulated copper, (copper shot) are now mixed with ten pounds of calamine calcined and pulverized, and about one bushel of charcoal. One handful of this mixture is then put into a casting pot, and then three pounds of the granulated zinc, upon which the composition before specified is laid till the vessel is filled. Eight similar pots are to be supplied with the same materials, and the whole must be submitted to the heat of a furnace for 12 hours, when the process will be completed, and 82 lbs. of brass will be

procured, which he says will be of a very superior quality to that procured from copper and calamine alone.

This process like most other patent specifications, requires explanation.

1. It is evident that the pots must be furnished with covers otherwise the zinc will sublime and be wasted.

2. The degree of heat is not mentioned, whether the copper should be quickly melted or not, which in the common process for making brass does not take place till the latter end of the process.

3. Much must depend on the analysis of the calamine. Some calamine contains lead, all contain iron. Calamine varies in its contents of zinc from 45 to 65 per cent. According to Watson, calamine from Poland yielded out of 16 parts 2 parts and an half: from Breslaw 4 parts and an half: from Hungary 2 parts and one-third: English calamine three parts: another specimen from Holywell in Flintshire 7 parts.

I copy the following from 2 Jamison's Mineralogy 413. Calamine English.

	From Holywell.	Derbyshire.	Somersetshire.	Wantock head.
Ox. of zinc	65	65.2	64.8	66
Ox. of iron	1			33
Carb. acid	28	34.8	35.2	
Water	6			
	100	100	100	100

German Calamines from Fribourgh 36 oxyd of zinc, 52 silica, 12 water: from Bleyberg 71.4 oxyd zinc, 13.5 carbonic acid, 15.1 water.

Hence according to the analysis of Jamison in this process of Emerson's, ten pounds of calamine may be supposed to yield six pounds and a third of zinc, which with three of granulated zinc for each pot will make thirty pounds and one-third of zinc to fifty-four of copper: if the produce be 82 lbs. then two pounds and one-third

will be dissipated. This is a very large proportion of zinc, and would form what is called Prince Rupert's metal.

The following observations of Bishop Watson, are worth attention.

The calamine of *Bohemia* contains iron: most of our English calamine contains lead; and there are some sorts which contain both iron and lead, and other metals in different proportions: these sorts can seldom be freed from the extraneous metals, and hence, in the ordinary method of making brass, they will be mixed with it, being fusible in the degree of heat usually employed in making brass. *Cramer* mentions a very ingenious method of making brass, by which, if it should be thought necessary to do it, the brass may be preserved pure from these heterogeneous mixtures. He orders the calamine and charcoal to be mixed with moistened clay, and rammed to the bottom of the melting pot, and the copper mixed with charcoal to be placed upon the clay; then, the proper degree of heat being applied, the vapour of the zinc contained in the calamine will ascend through the clay, and attach itself to the copper, but the iron, or lead contained in the calamine, not being volatile, will remain in the clay, and the brass when the whole is melted will not be mixed with them, but rest pure on the surface of the clay. Mr. *John Champion*, brother to him who first established the manufactory of zinc at Bristol, is a very ingenious metallurgist, and he has lately obtained a patent for making brass by combining zinc in vapour with heated copper plates, and the brass is said to be very fine; whether the process he uses has any correspondence with this mentioned by Cramer, or not, his brass will certainly be free from the mixture of lead, &c. But the care to purify brass from such metallic mixtures as may be accidentally contained in the calamine, is, or is not necessary, according to the purposes

to which brass is applied. These mixtures may probably injure the malleability of the brass, but they may at the same time increase its hardness, or render it susceptible of a better polish, or give it a particularity of colour, or some other quality by which it may be more useful in certain manufactories, than if it was quite free from them, and consisted of nothing but of the purest metallic part of the calamine, united to the purest copper. This may be illustrated from what is observable in other metals. The red iron ore from *Furness* in *Lancashire* produces an iron, which is as tough as *Spanish* iron, it makes very fine wire; but when converted into bars, it is not esteemed so good as that which is made in the forest of *Dean*, and other places. There are but few sorts of iron which, though useful in other respects, are fit for being converted into steel: some sorts of iron will admit an high polish, as may be seen in many expensive grates which are sold as grates of polished steel, though they are nothing but iron, whilst others take but a very indifferent polish; the *Swedish*, *Russian*, and *English* irons, and even the irons made at different furnaces in the same country are respectively fit for some purposes, and unfit for other; he who should attempt to use the same iron for the making of wire, and for coach and waggon wheels, would betray great ignorance in his business. In like manner, a notable difference may be observed in different sorts of copper, yet all of them have their respective uses: the Swedish copper is more malleable than the copper of Hungary; the copper of Anglesea differs from the copper of Cornwall and of Staffordshire. The braziers prefer that copper which they can work with the greatest facility, but the malleability of copper should not be esteemed the only criterion of its goodness; for the copper which is less malleable may admit a finer polish, and may last longer when exposed, as in breweries, in the navy, &c. to the action of the fire, than the copper which

is more malleable. This has been proved by experiment. Three plates of copper, equal to each other in surface and thickness, were exposed, for the same length of time, to a violent fire, with a view of seeing which would best sustain its action; one plate was made of copper which had been purified by a chemical process, another was made of copper from Hungary, and the third of Swedish copper. The purified copper, when freed from the calcined scales, had lost 5 grains of its weight, that of Hungary had lost eight, and that of Sweden eleven grains.

[4 *Watson* 63—69.

This last experiment can be accounted for, inasmuch as copper is less oxydable than iron or lead or antimony, and therefore the purer it is the less apt it will be to scale off. T. C.

Prince's Metal (Prince Rupert). This metal was prepared by Admiral Prince Rupert, in 1682. Three parts copper being melted and covered with charcoal, one part of zinc is added, and the vessel covered close. Or 8 parts brass being melted, one part of zinc is added with charcoal, and the vessel covered.

Pinchbeck.—This is a redder metal, made by fusing one part of brass with one and a half or two parts of copper.

Tombac.—Three and a half of copper to one and a half of brass.

Or de Manheim. Similor.—Marggraf melted pure zinc and pure copper together, in a great variety of proportions, and he found that eleven, or even twelve parts of copper being mixed with one part of zinc, (by putting the zinc into the copper when melted) gave a most beautiful and very malleable tombac or pinchbeck. Mr. Baumè gives the following process for making a metal, which he says is called *Or de Manheim*, and which is used for imitating gold in a variety of toys, and also on lace.—Melt an ounce

and an half of copper, add to it three drams of zinc, cover instantly the mixture with charcoal dust to prevent the calcination of the zinc; this covering of the melted mass with charcoal is certainly serviceable in the way the author mentions; and it is on a similar principle, that when they melt steel at Sheffield they keep the surface of it covered with charcoal; but I think it probable also, that the charcoal contributes to exalt the golden colour of the pinchbeck. These yellow metals are seldom so malleable as brass, on account of the zinc which is used in making them not being in so pure a state, as that is which is combined with copper when brass is made; yet it appears from the experiments of Marggraf and Baumè before mentioned, that when pure zinc and pure copper are used in proper proportions, very malleable brass may be made thereby. Mr. Emerson has a patent for making brass with zinc and copper, as I have been informed, and his brass is said to be more malleable, more beautiful, and of a colour more resembling gold than ordinary brass is. It is quite free from knots or hard places, arising from iron, to which other brass is subject, and this quality, as it respects the magnetic needle, renders it of great importance in making compasses. [4 *Watson* 45—48.

The last observation of Bishop Watson agrees with the experiments of M. Cavallo, who found almost all the specimens of brass he tried, to be magnetic. The great inconvenience of this property, when the case of the compass is brass, is obvious. T. C.

Mesure's Metal. Substitute for Gold.—Mr. Mesure of Craven-buildings, Drury-lane, having been, in consequence of the great scarcity and exorbitant price of gold, induced to turn his attention to the discovery of a substitute for that metal, has at length announced the complete success of his exertions. The metal which is the result

of them approaching nearer to the qualities of gold, except in weight, than any other yet discovered. It takes a most beautiful polish, is less liable to tarnish or to be scratched than gold, and though very ductile, it is capable of being rendered extremely strong and elastic: It is peculiarly adapted for watch cases, snuff boxes, and all the variety of trinkets for which gold is at present employed: the inventor supplies the unwrought metal at a very reasonable rate.—4 *Com. Mag*. 362.

A summary of these alloys of copper and zinc, and copper and tin, is given by Aiken as follows:

Copper with Zinc. Copper nearly saturated with zinc, that is, in which the latter makes about a fourth (more or less) of the mixture, forms *brass*, the most important of all the alloys of this metal, and which has been fully described under that article. With a much less proportion of zinc the colour of the alloy approaches very nearly to that of gold, and the malleability increases. Mixtures chiefly of these two metals are used to form a variety of yellow or gold-coloured alloys, known by the names of *Tombac*, *Manheim or Dutch Gold*, *Tinsel*, *Similor*, *Prince Rupert's Metal*, *Pinchbeck*, &c. but the precise composition varies according to the fancy or the experience of different manufacturers. The Dutch gold may be beaten out into extremely fine leaves, which, when fresh, have nearly the brilliance of gold-leaf, and are used as a cheap imitation of it, but they tarnish very soon. The mixture may be made either by directly melting copper and zinc, or by mixing brass and copper. In either case the copper should be melted first, and the zinc added afterwards, the whole stirred together with wood, covering it with a little charcoal, and poured out immediately, to prevent the loss by the burning off of the zinc.

Several direct experiments on the union of copper and zinc in different proportions were made by Marggraf.

In all, the copper was the purest Japanese, and the mixture was made in the way above mentioned. With 8 drams of copper and as much zinc, much of the latter unavoidably burnt off and the alloy only weighed 12 instead of 16 drams, the mixture was hard, brittle, yellow, and of a radiated texture. With 16 drams of copper and 8 of zinc, the loss by burning was only one sixth of a dram. The alloy was softer than the last, still radiated, yellow, and began to be a little malleable. From this, successively diminishing the proportions of zinc, the alloy became softer, more malleable, and of a colour more and more approaching to gold: and at last, with 11 or 12 of copper and 1 of zinc, the finest golden tombac was produced. According to Wiegleb the Manheim gold is made by melting separately 3 parts of copper and 1 of zinc, mixing them, covering with charcoal, stirring with a stick and cooling immediately. These proportions scarcely differ from those of some kinds of brass. Beaumè gives for the same metal 4 of copper and 1 of zinc, whence it is obvious that the proportions are quite arbitrary, but it appears that the alloy is not made, as brass is by cementation, but by simple mixture of the metals. A very small quantity of tin is sometimes employed, but this metal has the disadvantage of remarkably diminishing the malleability of copper and its alloys. A fine malleable tombac is made, however, with 16 of copper, 1 of zinc, and 1 of tin. An alloy of 12 of brass and 1 of tin is scarcely malleable.

A kind of tombac is the material of which a large proportion of the Roman coins was composed. Klaproth on analyzing several, struck during the first century of the emperors, found them all to consist either of pure copper, or of copper and zinc, in which the latter metal made generally from a fifth to a sixth of the mass. A little tin

and lead were found in some, but in such small proportion as to appear only an accidental impurity.

Copper with Tin.—The alloys of copper and tin are extremely important in the arts, and curious as chemical mixtures. They form in different proportions mixtures which have a distinct and appropriate use. Tin added to copper makes it more fusible, much less liable to rust or corrosion by common substances, harder, denser, and more sonorous. In these respects the alloy has a real advantage over unmixed copper, but this is in many cases more than counterbalanced by the extreme brittleness, which even a moderate portion of tin imparts, and which is a singular circumstance considering how very malleable both metals are before mixture, and the remarkable softness and ductility of tin.

The sensible qualities of the different mixtures are the following. Copper alloyed with from 1 to about 5 per cent. of tin is much harder than before, the colour yellow with a cast of red, and the fracture granular. It is still considerably malleable. This appears to be the usual composition of many of the very ancient copper tools and weapons before the common use of iron; whence it appears that the ancients did not (as has often been supposed) possess any peculiar art of hardening pure copper, otherwise than by mixture. It is certain that the quenching of red hot copper in water will not at all make it harder, or have any such effect as it has upon iron. An alloy in which the tin is from one-tenth to one-eighth of the whole is hard, brittle, but still a little malleable, close-grained, and yellowish-white. Where the tin is as much as one-sixth of the mass, it is now entirely brittle, and continues so in every higher proportion. The yellowness is not entirely lost till the tin is above 7-23ds of the whole.

Copper, or sometimes copper with a little zinc, alloyed with as much tin as will make from about one-tenth to

about one-fifth of the whole, forms an alloy which is the principal, and often the only composition for bells, brass cannon (so called) bronze statues, and several smaller purposes, and hence it is called *Bronze*, or *Bell-Metal* (always observing that there is no perfect uniformity in the different alloys under these names, either in the proportion or the actual number of ingredients) and it is excellently fitted for these purposes, by its hardness, density, sonorousness, and fusibility, whereby the minute parts of hollow moulds may be readily filled before it fixes in cooling. For cannon, a lower portion of tin seems to be used. According to Dr. Watson, the metal used at Woolwich is 100 parts of copper and 8 to 12 of tin. Hence it still retains some little malleability, and of course is tougher than with more tin. Bronze cannon are much less liable to rust than those of iron, but in large pieces of ordnance, by very rapid firing the touch-hole is apt to melt down and spoil the piece; of which there is a remarkable instance at the Tower of London of a mortar of the largest calibre thus spoilt at the siege of Namur. On account of the sonorousness of bronze, these cannon give a much sharper report than those of iron, which for a time impairs the hearing of the people that work them. A common alloy for bell-metal is about 80 of copper to 20 of tin; or where copper, brass, and tin are used, the copper is from 70 to 80 per cent. including the portion contained in the brass, and the remainder is tin and zinc. The zinc certainly makes it more sonorous. Antimony is also often found in small quantity in bell-metal. Some of the finer kinds used for small articles contain also a little silver, which much improves the sound.

When the tin is nearly one-third of the alloy it is then most beautifully white, with a lustre almost like that of mercury, extremely hard, very close-grained, and perfectly brittle. In this state it takes a most beautiful polish,

and is admirably fitted for the reflection of light for all optical purposes. It is then called *speculum metal*, which however, for the extreme perfection required in modern astronomical instruments, is better mixed with a very small proportion of other metals particularly arsenic, brass, and silver. But the basis of these compositions is copper alloyed with nearly half its weight of tin. The use of this alloy for the same purpose is of great antiquity, and certainly was in frequent use in the time of Pliny. Klaproth analyzed a portion of an ancient speculum in the following manner. The fragment was compact, very hard, and brittle, the fresh fracture greyish white, which by polishing acquired a beautiful lustre. A hundred grains were heated with nitric acid, whereby a blue solution was made, and a part remained undissolved. The solution being first tried without effect with muriat of soda for silver, was mixed with a solution of sulphat of soda, which gave a white precipitate of sulphat of lead, equivalent to six grains of lead.* The copper was then separated by iron, and amounted to 62 grains. The undissolved portion slowly digested with muriatic acid, gave a straw-yellow solution, which, decomposed by zinc, gave 32 grains of metallic tin. This speculum therefore consisted of 62 parts of copper, 32 of tin and 8 of lead, which last was probably an adulteration of the tin and not added designedly.

When more tin is added than amounts to half the weight of the copper, the alloy begins to lose that splendid whiteness for which it is so valuable as a mirror, and becomes more of a blue-grey. As the tin increases, the texture becomes rough-grained, and, as it were, rotten, and totally unfit for manufacture. The speculum metal is therefore in the highest proportion of alloy of tin that copper will admit for any useful purpose.

A perfect speculum-metal should be quite white with-

out shewing any cast of yellow when polished, not very liable to tarnish, quite free from pores even when examined by a lens, of a certain coherence or toughness to bear the grinder, and for the convenience of working, as soft as may be consistent with the other requisites.

Mr. Mudge, whose specula were celebrated for their goodness, observes, that the extreme of whiteness is given by 32 parts of copper and 16 of tin, but this is excessively hard and brittle; that 32 of copper with 14 1-2 of tin is still quite white and as hard as can be wrought. He also observed by many trials, that the metal to turn out free from pores should be twice fused, that is, the first time for the purpose of mixture (in which the copper is to be first melted separately) and then remelted with as little heat as possible, for casting. As there is always some loss by the calcination, chiefly of the tin, a little allowance in the proportion of this latter may be made on account of the double fusion.

The most elaborate mixture and accurate directions on this important subject are given by Mr. Edwards, whose specula are of extreme excellence, and are published in the nautical almanac for 1787, of which the following are the leading particulars.

The quality of the copper should first be tried by adding successively from so much short of half its weight of tin that it proves a little yellow, to the full half of tin, and by comparison ascertaining the maximum of whiteness, observing that beyond this point the alloy begins to lose part of the brilliance of fracture and to become bluish. When this is found, take 32 parts of the copper, melt it, add one part of brass and as much silver, with a little black flux* to cover the surface; when these are melted, stir with a wooden rod, and pour in from 15 to 16 parts of tin (according as found necessary by previous experiment) fused in a separate crucible with a low heat, stir the

* Crude Tartar deflagrated with nitre. T. C.

mixture again, and immediately pour it into cold water. Then in the second melting (with as little heat as will suffice) take for every 16 parts of the composition 1 part of white arsenic, wrap it in paper, thrust it to the bottom of the fluid metal, and stir with a wooden rod till no more arsenical fumes escape, immediately after which cast the metal in a sand-mould. Then while it is still red-hot lay it in a pot full of very hot embers and cool it very slowly: unless this precaution is particularly observed, the metal will fly in pieces when cold, sometimes even long after all such danger is thought to be past; or it will split in the polishing. For the particular manner of constructing the mould, and the whole of the nice and laborious operations of grinding and polishing to a perfectly true figure, the reader is referred to the two papers above mentioned.*

Both the brass, and the silver, and the arsenic appear to have their distinct use. The brass makes the mixture tougher and not so excessively hard and brittle. The silver improves both the texture and colour, but is not an essential though really an useful addition. The arsenic is found by actual comparison to make the metal finer, and particularly closer in texture, and therefore less liable to be porous. It sensibly increases the specific gravity, which, before the arsenic is added, is 8.78, but afterwards, 8.89. It is added in the second melting, that as little as possible may be dissipated in vapour. A greater proportion would make the metal liable to tarnish. An alloy containing 6 of copper, 2 of tin, and 1 of arsenic, is nearly the proportion of Sir I. Newton's specula, which is very good, but polishes somewhat yellow.

The separation of copper from bell-metal and all the tin alloys in the large way, happened to be an object of considerable importance in France in the midst of the revolutionary war, when the importation of copper was nearly impracticable, and a large quantity of it was required for

* And to a paper in part extracted a few pages hence. T. C.

general purposes, and particularly for the coinage. A number of very ingenious experiments were then made on the best method of freeing the metal of church bells from their tin and other alloy, and obtaining thence a good malleable copper with the least possible expence or loss.

The circumstances in which it is worth while to melt down great bells for the sake of the pure copper do not often occur, but the various processes may be here shortly noticed as important to the history of the chemical properties of copper alloys, and as a very happy example of the application of theoretic chemistry to the purposes of manufacture. Pelletier and Fourcroy seem to have chiefly distinguished themselves in this research, and each chemist appears to have followed nearly the same track, but with an acknowledged priority in the former.

The great principle on which all the modes of purifying bell-metal depend, is the much more ready oxydability of tin by the united action of heat and oxygen, than copper. Hence even when bell-metal is simply kept melted in an open vessel, a degree of separation of the two metals begins instantly, the tin oxydating much faster and sooner than the copper, and of course the proportion of copper being therefore constantly increasing in the fluid metal below.

Another equally important circumstance also depending on the much stronger affinity of tin for oxygen, is, that when oxyd of copper is mixed with tin at its lowest state of oxygenation, the tin still retains its superior affinity for oxygen, and deprives the oxyd of copper of this principle, and the products are, tin highly oxygenated and in a pasty semi-fluid mass, and copper in the reguline state, partly collected at the bottom of the vessel and partly in small globules entangled in the oxyd of tin.

The direct experiments of Fourcroy on this point are valuable.

A bell-metal was first made with 80 parts of copper and 20 of tin, both pure.

Of this alloy 100 parts were put on a muffle and exposed for a certain time to a red heat, with access of air. The whole was converted to a grey oxyd and weighed 104 parts. It was then heated strongly for half an hour, and yielded a button of pure copper weighing 54 parts. Consequently 26 parts of copper remained unreduced and mixed with the scoriæ of the oxyd of tin.

A hundred parts were calcined as above till they increased to 117. This being strongly heated for half an hour gave a brown mass, from which no copper separated except a few interspersed globules. This therefore was too much oxygenated, that is, the tin had combined with so much oxygen in the first operation that it could not afterwards separate any from the oxyd of copper.

A hundred parts were treated in the same way till they increased to 112. This melted into a brown mass containing more globules of copper than the last, but still the greater part remained unreduced.

Hence it appears that even an increase of 12 on 100 is too much, and by other experiments, the above chemist fixes the proper point of oxydation at which oxyd of copper is reducible by oxyd of tin to be from 5 to 7 on 100 of common bell-metal. However, when too highly oxygenated metal is mixed with the requisite proportion of fresh metal, the former serves as a reducing flux to the latter, and the whole may then be made to yield a large portion of purified copper. This very ingenious plan has been found to answer extremely well in experiments made in the large way, as will presently be mentioned.

Several substances have been tried that might assist in the first oxygenation of the bell-metal and shorten the process. Of these, nitre and oxyd of manganese answer the most completely. For experiment in the small way, 100

parts of bell-metal were powdered and mixed with about 14 of nitre, and heated, at first slowly, afterwards strongly, and gave from 57 to 63 parts of copper, very malleable, but not quite pure. With a larger quantity of nitre the copper is purer, but more is lost in the scoriæ.

A hundred parts of bell-metal mixed with 25 parts of oxyd of manganese, covered with broken glass, and strongly heated for an hour, gave 36 parts of very good copper. It is of some importance to add glass or some other saline flux, as this brings the whole into thorough fusion, and allows the copper to subside through the vitrified oxyd of manganese. Where this is not done (and in the large way it would add to the expense) much of the copper is entangled in the vitrified manganese, and a subsequent operation is required to separate it.*

In the processes of two other chemists, salt and sand have each been found useful additions in the refining of bell-metal.

We may add the detail of two trials made in the large way by Pelletier and Darcet by order of the French government, the one in which a portion was first oxydated, and this used as a reducing flux for the remainder, without any foreign addition whatsoever: and the other in which the refining was assisted by oxyd of manganese. It may be premised that the manipulation of large quantities is not the same as with small, particularly in the case of reduction to gross powder, which may be easily done in an iron mortar on a few ounces or pounds, but not with any economy on large weights. Large masses therefore are first heated red-hot, when they may be easily broken up and spread about by an iron bar, and this is the way constantly practised.

The first process was that of refining without addition. For this purpose 400 pounds of metal were put on a furnace, and when red-hot broken up with an iron bar, and

* All this strongly bears upon the refining of Copper.

spread about with constant stirring till the whole was converted into a reddish oxyd, somewhat cohering, and shewing the appearance of copper approaching to reduction. The 400 pounds were increased hereby to 425 pounds 2 ounces, making an increase of above six and one-fourth on 100.

Next, 800 lbs. of fresh metal were melted on a reverberatory, and the 425 lbs. 2 ounces of oxyd were added to it with constant stirring for about twenty minutes. The fire was continued for nine hours with occasional stirring of the metal, and samples were drawn from time to time, which shewed a gradual approach in the melted metal to the state of pure copper. As the refining took place at the surface of the fluid metal, or the point of contact between it and the scoriæ, the metal was there purer than at the bottom. Nine hours after the melting of the metal the copper beneath the scoriæ was fine, red, and fibrous, and was then run off into moulds. The scoriæ remained in, for half an hour longer to melt out part of the metal entangled in it, which was then let out, and lastly, the scoriæ itself was raked out, which was a black and pasty mass, that hardened excessively when cold, and still contained some copper entangled in its substance. The results of this operation were 761 lbs. 12 ozs. of copper run into the moulds; 46 lbs. of copper sweated out of the scoriæ, and 7 lbs. 4 ounces of small-grained copper, samples, &c. or in total 915 lbs. of copper from 1200 of metal, or nearly 68 from 100. The scoriæ weighed 474 lbs. and when thoroughly bruised in a stamping mill, and washed, it gave 18 lbs. more of copper.

Thus then by this simple process nearly 70 parts (in all) of very good copper may be got from 100 parts of metal, whose known contents of copper are about 80 per cent.

The second process was that with the assistance of black oxyd of manganese.

In the same furnace 800 lbs. of bell-metal were first melted, and kept very hot, after which 25 lbs. of oxyd of manganese were thrown in, and the whole stirred and mixed with great care. Two hours after, 15 lbs. more of the manganese were stirred in, and the metal even then was sensibly purer than at first. This alternate addition of manganese, and stirring, continued till 100 lbs. of manganese were used, during which the metal constantly kept refining. Ten hours after the first melting, the copper was found to be soft, fibrous, and good, and was run off into moulds. It weighed 520 lbs. The scoriæ was softer than the former, and not so well melted. It weighed 344 lbs. and was still visibly rich in copper, as was proved by after washing. The copper, exclusive of that in the scoriæ, here amounted to about 60 from 100 of bell-metal.

From these and many other experiments it appears that by very simple means from six to seven-eighths of the copper actually contained in bell-metal may be extracted; and in particular circumstances this may be practised to advantage, but on the other hand the tin is lost to most economical uses, as its reduction from the state of an impure semi-vitrified scoriæ is extremely difficult and expensive. [1 *Aikin*, 347.

Copper with Iron.

These only unite when the iron is in small quantity. The alloy is grey, hard, and somewhat brittle.

Tutenag is a white alloy of copper, zinc, and iron, according to Keir, which is very hard, tough, and sufficiently ductile to be wrought into various articles of furniture, such as candlesticks, &c. which take a high polish, and when made of the better sort of tutenag, are hardly distin-

guishable from silver. The inferior kinds are still white, but with a brassy yellow.

The Chinese *Petong* is another fine, white, malleable alloy of copper, the composition of which is not exactly known, but it contains a small portion of silver. Neither of the above metals are imitable by the common processes.

According to Dize, when the iron forms only $\frac{1}{76}$ of the mass it is still magnetical, but not so when it is only about $\frac{1}{80}$. Iron does not whiten copper so much, in equal quantities, as tin does, and still less than arsenic.

[1 *Aikin*, 346.

Bronze, the name of a mixed metal, which the ancients employed for casting statues and other ornaments. According to Vasari, the bronze of the Egyptians consisted of two-thirds of brass, and one of copper; and Pliny informs us, that the Greeks added to the brass one-tenth part of lead, and one-twentieth part of silver.

In casting bronze figures, particular attention must be paid to the formation of the mould. The pattern from which the cast is to be made must have a mould made upon it, with a mixture of one-third of plaster of Paris, and two-thirds of brick-dust. Its thickness should be proportioned to the weight of the figure; and small air-holes, opening upwards, should be made in the joints, to give free passage to the air, which is thrust out by the entrance of the metal. Over the interior surface of the mould there should be spread neatly a layer of clay of the intended thickness of the metal. When this is done, the concavity, which is bounded by the layer of clay, is to be filled with the composition of plaster of Paris and brick-dust already mentioned, which will form the core. When the figure is long, strong bars of iron must be laid in the mould as a support to the metal figure, and round these the core must be cast. The mould is then opened, the

layer of clay taken out, and every kind of dampness expelled, by drying the mould and core with charcoal or lighted straw. The core is then replaced in the mould, where it is supported in its proper position by short bars of bronze, which run through the mould into the core. The mould being strongly fortified with iron bars, and fixed in a right position, the liquid bronze is poured into the mouth of the mould.

Bronzing, is the art of imitating bronze, or of communicating to figures in wood, ivory, plaster, &c. that greenish rust which distinguishes the bronze figures of the ancients. The golden bronze is made of the finest and brightest copper dust, and when it is wanted of a red colour, a small quantity of red ochre, well pulverized, is added. They are both put on with varnish, and the body to which they are applied is immediately dried over a chafing dish, to prevent it from turning green.

The following method of bronzing figures is extremely simple. After having covered the figure with a coat of gum water, mixed with a little minium,* take a little fish glue,† dissolved in spirits of wine,‡ by exposing them in a warm place, and add to it some saffron; then take the filings or dust of any metal which it is wanted to imitate, and apply this, when mixed with the glue, to the figure, with a hair pencil.

In bronzing copper, the Chinese first rub it with vinegar and ashes, till it is well polished. When the copper is well dried in the sun, they cover it with a coat, made in the following manner. Take two parts of verdigris, two parts of cinnabar, five parts of sal ammoniac, two parts of the bill and liver of ducks, five parts of alum; pound and mix them well, and form them into a clear paste. The copper, after being covered with a coat of this paste, is dried, cooled, and washed, and the same operation is repeated about ten times.

* Red Lead. † Isinglass. ‡ Or 4th proof brandy.

Iron may be bronzed merely by rubbing it when hot with the hoof of a cow, and with oil.—*Brews. Ency.*

The *Gong* is composed of 78 parts of copper and 22 parts of tin. The *Packfong* is copper and tin with about one-third of nickel.

Copper with Lead.

These metals unite to appearance very intimately by fusion, but, what is very remarkable, when a mass of this alloy is exposed to a heat less than that at which the whole melts, the lead alone sweats out, leaving almost all the copper in a porous or honeycombed state. When the copper holds a small portion of silver, the lead carries the latter out with it, and this is the principle of the old process of *eliquation*, formerly much used in the extracting of SILVER from copper ores. Copper with about a fourth of its weight of lead forms *pot-metal.* The ancient Roman pot-metal, according to Pliny, was composed of 100 of copper, 2 of lead, and 2 of tin. The same ingredients, but with more of the two latter, were the materials of many of the ancient Greek and Sicilian coins.—1 *Aik.* 347.

Ancient Weapons and Coins.

The ancient weapons both shields and swords were for the most part made of copper hardened with tin. I recollect but one place in Homer where iron is mentioned as the metal employed for the purpose, and that was the point of the spear, wherewith Pandarus wounds Menelaus. The word is, Sidèron. Il. 4. T. C.

Hardening Copper.—In the second vol. of this work, old Series, conducted by Dr. Coxe, is an account of Le Sage's method of hardening copper by phosphorus. The process will succeed, but when so hardened, the metal is so brittle as to be fit for no purpose whatever.

The same may nearly be said of the process of hardening and whitening copper with arsenic. Melt the cop-

per: cover it with charcoal: to two parts of copper by weight, add, tightly folded up in paper, one part of a mixture of equal weights of potash and arsenic fused together; putting in the arsenic when the potash is quite hot. As soon as you have thrust this to the bottom of the melted copper with a stick, cover the crucible quickly, and lute the sides of the cover. In a quarter of an hour, the mixture may be poured out. It will be hard, white, and very brittle. Where the latter quality does not spoil it, this alloy may be used, as a substitute for silver. Perhaps brass thus treated with arsenic, might be used to good purpose. T. C.

Plating.—This is confined to the covering of copper or brass, the metals usually employed for this purpose, with a plate of solid silver. The other methods of covering copper or brass with a still thinner coating of silver, is called *Silvering*.

Plating is thus performed. An ingot or bar of copper, previously well hammered to increase its ductility, and neatly cleaned and planished, is covered with a very thin coating of pounded and finely-sifted glass of borax: upon this, is laid a plate of silver from one-tenth to one-sixteenth part of the weight of the copper, according to the proposed value of the plated goods. The plate of silver is very nearly but not quite so large as the bar of copper. The silver is also planished, so that previous to the operation, the under surface of the silver and the upper surface of the copper may touch nearly in all their parts. The silver being laid on the copper, previously strewed very thinly with the sifted borax, a few blows with a hammer or mallet are given, to bring the surfaces still more into contact. The silver is then bound to the copper by iron wire drawn tight. The edges are also covered with powdered and moistened glass of borax so as to cement the silver, when heated, to the copper. They are then ex-

posed to a considerable heat approaching to, but short of melting. The very thin coating of interposed borax, assists in preventing any oxydation of the surface of the copper, while it is too thin to prevent the adhesion of the metals. The double plate is then passed through well polished steel rollers, till it be of the required thinness : the silver and copper being diluted by the pressure, equally.

An ounce of silver is often rolled out to a surface of about three square feet and its thickness does not exceed the three thousandth part of an inch. Hence the silver is easily worn off the sharp edges of plated copper : an inconvenience remedied to a certain degree of late years, by using for the edges of plated ware, copper more thickly plated than in those parts of the utensil not so much exposed to friction.

When plated candlesticks for instance, after long use, begin to shew the copper from the silver being worn off, it may easily and cheaply be renewed, by mixing the precipitate of silver from nitric acid by means of common salt with two parts in quantity of whiting, two parts of common salt, and two parts of cream of Tartar. Those who are not chemists may make this paste thus. Send to the druggists for a quarter dollar's worth of Luna cornea, or Lunar caustic : moisten it in a teacup and mix it into a paste with twice and even thrice its bulk of each of the other ingredients above mentioned. When the candlesticks are cleaned, either with the finger or a soft cork rub the parts where the silver is worn off: the copper becomes almost instantly covered with a coating of pure silver, thin indeed, but which can be renewed at a small expence. T. C.

French plating, is managed by the application of silver leaf to copper or brass well cleaned and planished and then heated quickly, so as not to allow time for oxydation.

The silver leaf laid on the heated metal, is then bur-

nished down. Successive coatings of silver leaf may be thus given.

Silvering, on copper and brass may be performed by the muriat of silver mixed with whiting, common salt and cream of tartar in the way I have mentioned. The whiting should be previously washed and the first coarse sediment permitted to subside: the sediment of the supernatant liquor should alone be used, either for this purpose or any purpose of cleaning silver or brass; because, the common whiting is apt to have gross particles of sand in it, that will scratch the surface.

Or, to a solution of silver in aqua fortis, add some clean plates of copper: the silver will be thrown down in a fine powder in its metallic state. Separate it from the surface of the copper, and wash it well. Of this powder take one part, common salt and sal ammoniac four parts by weight, corrosive sublimate one fourth of a part. Rub them well together in a mortar with a little water, into a paste. Clean the vessel to be silvered by any dilute acid, or by common salt and tartar: rub it with this paste till it acquires a metallic coating, which will be an amalgam of mercury from the corrosive sublimate with silver, produced by the triple action of the silver, the copper, and the mercurial salt. Wash the coated surface; then expose it to heat so as to drive off the mercury, and the silver remaining on the copper, may be burnished in the common way.

Or, mix 20 grains of silver precipitated by copper, 2 drachms of tartar, two drachms of common salt, and half a drachm of alum. This composition being rubbed on a clean surface of brass or copper will cover it with a coating of silver, which may be polished with soft leather.

Or, take half an ounce of silver precipitated by copper from aqua fortis: grind it up with two ounces of sal ammoniac, two ounces of common salt, and one drachm of

corrosive sublimate of mercury, into a paste. Boil your copper for half an hour in alum and Tartar; take it out, and rub it with this paste. Then heat it red-hot, and afterward polish it.

When buttons are stamped out of plated copper, the edges and backs will be coppery. To whiten them, they are boiled in water containing as much argol or tartar as it can hold, in which precipitated silver is also put. The backs and edges are thus whitened, in the same way that the brass wire of pins is tinned.

I believe iron is plated on the same principles with copper and brass.

I do not know that any body has yet attempted to plate copper with *platina* except Dr. Bollman. His iron plated with platina, is a very beautiful manufacture, and would prove highly useful for crucibles, and culinary vessels; but I do not know that he has yet succeeded in plating copper with platina by lamination, in the same way as silver is rolled on copper. But copper may be coated with platina by means of a mercurial amalgam, as has been proposed and tried on the continent of Europe. The process is thus.

M. Strauss in Gehlen's Journ. 20 Phil. Magazine, 285. Take a solution of platina precipitated by sal ammoniac: wash it: dry it: expose it to a red heat in a covered crucible for half an hour. This may be amalgamated with from five to seven parts of mercury by trituration in warm water. (Why not use the precipitate hot?) This amalgam laid over copper, unites with it, and the mercury may be driven off by heat as in the case of silvering or gilding with mercury. A second coating may be applied, mixed with chalk and sprinkled with water: the plate is again exposed to a red heat to drive away the mercury. The platina may then be burnished down.

Tinning Copper.—The common method of tinning copper vessels, is first to scrape the inside clean from any rust; then to rub them with sal ammoniac; or while warm with rosin or fat: then melted tin is poured on the copper and by means of a cloth whitened with whiting to prevent the hot tin adhering to and burning it, spread evenly over the surface of the copper, and then planished.

The common tin used for this purpose is usually adulterated with lead which has been supposed to be very deleterious, but some French experiments on the subject have shewn that it is less so than was imagined.

The following papers on the subject of tinning copper vessels are worth noticing.

New Process for Tinning Copper and other vessels in a durable manner.

That copper and brass vessels cannot be used with safety in cooking victuals or for holding articles of food, and particularly those which contain acids, is well known. It is also well known that the tinning applied in the usual manner is not durable, being soon worn away by cleaning, and on that account must be frequently renewed. Some, therefore, have proposed enamelling for kitchen utensils of copper; which, indeed, would answer exceedingly well, and be much safer for the health than impure tin mixed with lead, often employed for tinning; but, unfortunately, enamel is too dear, and readily breaks when the vessel receives the least blow; which cannot always be avoided.*

* Articles that would come high when made singly, may be afforded at a low rate when manufactured on an extensive scale.—Cooking utensils lined with a vitrified glazing, are now commonly sold in many shops in London, and at a moderate price. It would be as reasonable to object to the use of earthen-ware or China, because they may be broken by blows, as to make this an objection against the use of glazed kettles.

The following process for tinning is attended with no danger from poisonous ingredients, as no lead is used in it; the tinning, too, is exceedingly durable, adds strength to the copper vessel, and secures it from the action of acids much longer than the common tinning:—When the vessel has been prepared and cleaned in the usual manner, it must be roughened on the inside by being beat on a rough anvil, in order that the tinning may hold better, and be more intimately connected with the copper. The process of tinning must then be begun with perfectly pure grained tin, having an addition of sal ammoniac instead of the common colophonium.* Over this tinning, which must cover the copper in an even and uniform manner throughout, a second harder coat must be applied, as the first forms only a kind of medium for connecting the second with the copper. For this second tinning you employ pure grained tin mixed with zinc† in the proportion of two to three, which must be applied also with sal ammoniac smooth and even, so that the lower stratum may be entirely covered with it.

This coating, which, by the addition of the zinc, becomes pretty hard and solid, is then to be hammered with a smoothing-hammer, after it has been properly rubbed and scowered with chalk and water, by which means it becomes more solid, and acquires a smooth compact surface.

Vessels and utensils may be tinned in this manner on both sides. In this case, after being exposed to a sufficient heat, they must be dipped in the fluid tin, by which means both sides will be tinned at the same time.

As this tinning is exceedingly durable, and has a beautiful colour, which it always retains, it may be employed for various kinds of metal instruments and vessels which it may be necessary to secure from rust.

* Rosin. † See the next paper.

Another durable, though somewhat expensive, Method of Tinning.

This tinning, which consists of more articles and is dearer than the former, can be applied to metals and metallic mixtures, and, when well prepared, is exceedingly durable; which makes up, in some measure, for the cost. It is as follows.—Take pure grained tin one pound, good malleable iron one ounce and a half, platina one dram, silver twenty-four grains, and gold three grains. These five metals must be well fused together in a crucible with one ounce of pounded borax and two ounces of pounded glass, and the liquid matter must be formed into small ingots. These ingots are to be again heated and reduced to powder in a warm mortar with a hot pestle. This powder is then to be put in an iron pan over the fire, where it must be again fused, stirring it well round: it is then to be poured into small flat moulds, where it is suffered to cool, and it is then fit for use.

This tinning is to be applied in the following manner. First tin the vessel with grained tin and sal ammoniac in the common manner; clean and scower this coating; then apply the composition with sal ammoniac according to the usual process, and when it is well diffused suffer the vessel and the tinning to cool. Then expose it every where to a gentle heat to render the adhesion stronger, and immerse it while hot into cold water to give it that hardness and solidity which it had lost by being heated. The surface is somewhat rough and gritty: but you then rub it hard with a scratch-brush; and, in order to make it even, you afterwards smooth it completely with fine sand or any polishing ingredient.

If one coating does not appear sufficient, a second, and even a third, may be applied in the manner above described. Two coatings, however, are fully sufficient for kitchen utensils which have been a good deal used; and

if you wish to have the surface perfectly smooth and even, you may apply a thin coating of tin, which will fill up all the cavities and render it quite even. A coal fire is the best for this tinning; for turf coals attack the metal, and interrupt the union and fusion of the coating.

[7 *Tilloch*, 218.

Extract from a work, published by Professor Proust, *entitled Researches on the Tinning of Copper, on Tin Vessels, and glazed Pottery; published at Madrid,* 1803.

THE author, in the introduction, says, that the motives which induced him to undertake this labour were the doubts spread abroad, two years before, among the public in regard to the salubrity of tinned copper, and the accounts of the disagreeable accidents arising from vessels badly glazed. Government, always attentive to every thing that can tend to calm the public mind, had recourse on this subject to sound chemistry; the only tribunal competent to banish doubts of this kind. Two problems were presented to the author to be resolved:

1st, Is the use of zinc advantageous or not, for tinning and for tin vessels?

2d, Can tinning, in consequence of the lead it contains, and sometimes in large quantities, expose the health of the public to the same dangers as glazing of a bad quality?

The author divides his work into three chapters, and each chapter into several paragraphs.

The first part, which may be considered as historical, is divided into four paragraphs.

In the first the author mentions the project which was presented by M. Malouin to the Academy of Sciences at Paris in 1741, in regard to the employment of zinc for tinning iron and copper; the advantages he promised

himself were only illusory, and his expectations have not been confirmed by time.

The second paragraph contains an account of a paper on tinning, presented to the same academy by J. B. Kemerlin in 1742. One may see there the examination of it by Messrs. Hellot and Geoffroy, who entertained an opinion contrary to the assertions of the author.

The same year the academy charged Hellot and Geoffroy to examine the alloys of zinc proper for making vessels. The inconveniences pointed out by the two academicians, as well as by many others, were verified by Proust; and all of them are inclined to proscribe such alloys. Having made a mixture of equal parts of lead and zinc, similar to that examined by the two commissioners, he obtained an alloy of a paste-like consistence, as easy to be cut with a knife as cheese, and difficult to be cast. M. Pierre Blanco, a very ingenious pewterer, seconded the labours of Proust. The first time he poured the alloy into the mould, it did not run sufficiently to fill it. He tried it a second time; and, when he thought he could draw it from the mould, it fell into pieces, as they had no cohesion. Being desirous to procure a piece well or ill moulded, he found himself obliged, at the third time, to cool his mould in cold water, and to employ double the time necessary to cast a piece of the same size with common alloys: the vessel obtained broke short, and was filled with defects which could not be remedied. A pound of alloy was employed, and the article weighed only nine ounces. The whole of the residuum was mere loss. The same article acquired in a month a dark colour, and at the end of six months was covered with oxyd; inconveniences which do not take place in vessels of common tin. The author still continues to make several practical objections, to which no one has given an answer.

It is seen, therefore, that alloys of zinc are not so advantageous as some have imagined; and those who propose them have neither consulted chemistry nor practice. Before they were presented to government for its sanction, it was necessary to subject these alloys to the test of chemical agents: and this the author has not omitted.

1st, A plate of the alloy in question being brought into contact with vinegar, the latter contracted a very disagreeable metallic taste at the end of a day: on the third day, without being sweet, astringent, or bitter, it occasioned in the throat a very uneasy and disgusting sensation, and no doubt a small dose of it would have excited vomiting.

2d, A plate of the same alloy, of four inches' surface, boiled half an hour in vinegar, lost 16 grains of its weight.

3d, Vinegar being boiled in a vessel tinned with the same alloy, acquired the same taste as No. 1.

4th, A plate of the same alloy, exposed cold in distilled vinegar, exhibited the same phænomena as No. 1 and 3. This solution, when attentively examined, did not exhibit an atom of tin.

All these facts, which confirm those of the French accademicians, prove that zinc is a metal exceedingly soluble in vinegar, very easily altered, and that solutions of it having been found noxious, it ought to be proscribed from our kitchens.

The subject of the third paragraph is the project of M. Doucet, who in 1778 presented to the Academy of Sciences at Paris a bar and pan made with a mixture of his invention. It was examined by Macquer and Montigni, who made a report on it. These two chemists, having more experience than Hellot and Geoffroy, analyzed it chemically, and, having soon found that it had its inconveniences, it was rejected.

The alloy of Chartier, and the project of Lafolie, shared the same fate, as is seen by the report of the commissioners, and by the labours of the abbe Monges and of Bayen.

The alloy of M. Buschaendorf, of Leipsic, presented in 1802, and described in the *Annales des Arts et Manufactures*, forms the subject of the last paragraph. Proust subjected it to the same experiments as the preceding: he proves that it is attended with the same inconveniences, without having any of the qualities announced by Buschaendorf

Part II.

On the Old Method of Tinning.

This part consists of ten paragraphs. M. Malouin, while he proposes his mixture, does not condemn the old, but he mentions the dangers to which people are exposed by this kind of tinning. Kemerlin, Hellot, Geoffroy, Doucet, Chartier, Lafolie, Buschaendorf, and others, have done no more: but no one has hitherto proved the reality of these supposed dangers; and what is still more astonishing is, to see the inactivity of the chemists of Europe in realising or exploding a fact which is so interesting to society. To decide the question in a peremptory manner, it was necessary to undertake a series of experiments which had before been neglected. To succeed in them it was previously necessary to examine the properties of some metals and oxyds; and there are nine paragraphs employed in the examination of iron, antimony, mercury, lead, and zinc. This examination was requisite to answer all the objections which he proposed to resolve in the third part of this work.

Part III.

This part is divided into five paragraphs.

Paragraph I.

Experiments made on the Old Method of Tinning.

Five plates of copper each a foot square, were tinned, all the necessary precaution being taken. The object of

the author was to ascertain the quantity of alloy they would take one with another.

The first took	-	144 grains
The second	-	178
The third	-	200
The fourth	-	208
The fifth	-	230

The quantity of tinning which copper can take is exceedingly variable, and not subject to calculation: the alteration of the copper by tinning being in all points the same, the variations in the weight must necessarily depend on the more or less exact manner in which the workman removes the superfluous tinning; and one might be induced to believe that the artist has it in his power to give a tinning more or less abundant; but the tinning not alloyed with the copper ought not to be considered in the same manner as that which is alloyed. The author has proved, in general, that good tinning takes a grain of tin per square inch.

Paragraph II.

On the Duration and Causes of the Destruction of Tinning.

Tinning with pure tin has a silver white colour, and, in contact with vapours capable of attacking it, assumes a yellowish tint. That made with one-third, one-fourth, or one-half of lead, like the old tinning, has more brilliancy, and may be easily distinguished from the former.

The causes which destroy tinning are friction, caloric, and acids: the effects of all these causes vary according to an infinite number of circumstances, which are determined by the author as exactly as possible, and have taught him, that, even supposing alloy to be made with one-half lead, no individual can swallow per day 1-20th grain of that metal; a quantity inappreciable in its effects,

since we daily swallow a hundred times more when we eat game, without being incommoded by it. From these facts, and many others, it results, that if vessels of tinned copper occasion illness, they ought rather to be ascribed to the want of tinning than to the latter.

Paragraph III.

Of Tinning considered as soluble in alimentary Acids.

Eight saucepans, each capable of containing twenty ounces of water, were tinned with the following alloys:

The 1st, with pure tin.			
2d, with tin having			0.05 of lead.
3d,	-	-	0.10
4th,	-	-	0.15
5th,	-	-	0.20
6th,	-	-	0.25
7th,	-	-	0.30
8th, with equal parts of tin and lead.			

Tinning with pure lead was impossible.

Into each of these pans there was put a pound of red wine vinegar, which was boiled till it was half consumed. The vinegar of each pan was poured into a glass vessel, and suffered to remain at rest for twenty-four hours. The vinegar was then poured off, and the precipitates were well washed: each portion of vinegar was mixed with an equal quantity of distilled water; equal parts of each were put into the vessels, and three rows were formed of eight vessels each. The vessels of the first and second rows contained vinegar; those of the third, sediments. Nearly four ounces of the sulphat of potash were poured into each vessel of the first row, and into those of the second and third row about four ounces of hydro-sulphurated water. In the first row no precipitate was observed, consequently there was no lead: in the vessels of the second row there was observed a slight chesnut-coloured sedi-

ment, which indicated the existence of tin. The sediments of the third row did not change colour, whence it was concluded that there did not exist in them any metallic substances. The vinegar, then, boiled in the tinned pans did not dissolve lead, but only a very small quantity of tin.

The sediments of the third row were, for the most part, composed of tartar and sulphat of lime. These two salts, in precipitating, might have carried with them a little lead; but they did not contain an atom of it.

The same experiments being repeated with very strong white wine vinegar, which was boiled till three parts of it were consumed, confirmed the preceding facts; with this only difference, that the tinning assumed the colour of lead, and readily yielded to the friction of the finger, coming off in the form of a gray powder, which was nothing else than very fine particles of lead. This phænomenon was more remarkable in the pan No. 8, though the quantity of that powder did not weigh half a grain. These facts were the less remarkable the nearer to the pan No. 1; so that with a little practice one might judge by these means of the quantity of lead and tin contained in tinning.

The vinegar formed zones of a very beautiful colour on the tinning of the pan No. 1. These facts may still serve to enable one to distinguish the quality of tinning. These experiments evidently prove that lead, which is very soluble in vinegar, loses that property when alloyed with tin. This is agreeable to chemical facts already known; for tin is more oxydable and soluble than lead, and the latter is precipitated from its solutions by tin, and this is the cause of the presence of the gray powder above mentioned; for vinegar, indeed, dissolves immediately a few particles of the lead in the tinning, but it is afterwards precipitated by the tin, and forms gray dust. All these facts, and many others explained by the author,

prove that tinning, the half even of which is lead, cannot be dangerous in domestic purposes; and that, to be hurtful to the health by the contact of alimentary acids, it would be necessary that the pans should be pure lead, or tinned with that metal only, which is impossible.

Paragraph IV.
On Tin Vessels.

It was necessary to examine the action of vegetable acids on vessels of tin. For this purpose the author caused the following vessels to be made:

1st,	Pure tin.	
2d,	Tin having -	0.05 of lead.
3d,	Ditto - -	0.10
4th,	Ditto - -	0.15
5th,	Ditto - -	0.20
6th,	Ditto - -	0.25
7th,	Ditto - -	0.30
8th,	Ditto - -	0.50
9th.	Of pure lead.	

All these vessels were filled with boiling vinegar, which was left in them three days. The vinegar of the first eight vessels being subjected to the examination of re-agents, did not give the least signs of the existence of lead, but of some particles of tin. The vinegar in the ninth vessel was much saturated with lead.

The same experiments, repeated at three other times, with vinegar of greater or less strength, exhibited the same phænomena. In these cases it was observed that the first eight vessels had assumed the colour of lead, and exhibited the same phænomena as those indicated in regard to tinning in the preceding paragraph.

The author, after supporting his observations by those of Bayen and those of Vanquelin, deduces this consequence: Tin alloyed with lead is harder than when it is pure, and less susceptible of suffering its particles to be

mixed with aliments. What have we to fear from such vessels? Small particles which may be detached by the fork or the knife? Such fears are groundless. Let us apply, then, to vessels of tin, in regard to their use, what we have said of tinning, that the fears entertained in regard to the employment of it are not proved by any facts well authenticated; and if the art of the pewterer is susceptible of improvement, either in regard to health or practice, it cannot be expected from mixtures which have always been rejected by sound chemistry. Besides, we know several other mixtures which might be tried before we have recourse to a metal so soluble, and so difficult to be worked, as zinc.

Let us now form a parallel of the alloys we have examined, with those used by the pewterers.

Pure tin forms the first quality, which they employ for the best utensils and those most esteemed.

The second kind of mixture contains an eighth of lead, and serves for making common vessels.

The third kind contains 0.15 of lead, and is employed for drinking-vessels.

The first kind, which is the most common, contains 0.20 of lead, and is employed for making ink-stands and other small articles.

From what has been said it may be seen, that if pewterers employ sometimes for common vessels the fourth kind of mixture, the public can be exposed to no danger. The ancients, who made so much use of tin vessels, have left us no certain facts which prove that the use of them was contrary to health, and medicine never proscribed them.

[21 *Till.* 313—319.

To Separate Copper from Silver, by M. Goetling.

Four methods are known for separating copper from silver, in all of which the alloy is dissolved in the nitric acid. As the price of this acid is high, M. Goetling, in

place of it, employs sulphuric acid, which is much cheaper. His process, which has fully answered his expectation, is as follows:

The proportion of silver in the alloy is first to be ascertained by the touch, or in any other way. For each part of silve, one part of sulphuric acid, and for each part of copper three and three-fifth parts of the same acid, are to be taken. The acid, diluted with half its weight of water, is to be poured into the matrass on the alloy, reduced to small pieces. An addition of one part more of the acid to every sixteen parts of the alloy facilitates the solution. Place the matrass in a sand heat, and bring the contents to a state of ebullition. If care be taken to stir it frequently with a glass rod, the alloy will be broken down and converted into a sulphat in two or three hours. It will become thick, and sometimes hard. While still hot, six or eight times its weight of boiling water is to be added to it, and the heat to be continued for some time. By this means the sulphat will be dissolved, and a great part of the sulphat of silver will be precipitated. When the whole is found to be completely dissolved, a clean plate of copper, or a few pieces of clean copper money tied loosely in a coarse cloth, is suspended in the fluid, and the boiling is continued for some hours, by which means all the sulphat of silver is decomposed, and the metal separated in a metallic form.

To ascertain when the separation is complete, a small quantity of the solution is taken out and tried, by adding a few drops of a solution of muriat of soda. If a curdly precipitate is formed, it is a proof that some of the silver still remains in it; in which case the boiling must be continued.

When a complete separation is effected, the clear solution is to be decanted off with care, and the precipitate washed. To ascertain that all adhering sulphat of copper

is removed, drop into the water last poured off from the precipitate a few drops of liquid ammonia. If any of that sulphat be still present, the ammonia will produce a blue colour in the water. The silver, if not wished to be kept as a powder, may be melted with from a fourth to a half of its weight of nitrate of potash.

The liquid sulphat of copper decanted from the precipitate, as also the water employed in washing it, may afterwards be evaporated in a copper basin, and, by crystallization, a quantity of blue vitriol equivalent to the cost of the acid will be obtained.

Should some parts of the alloy, by accident, have remained undissolved, they may be separated by decantation, and reserved for the next repetition of the process.

[21 *Phil. Mag.* 352,

This process is somewhat of a kin to that discovered by James Keir, Esq. of Birmingham. Take 10lbs. of oil of vitriol: dissolve in it 1lb. of nitre. This mixture will in a moderate warmth or even in the temperature of a warm day, dissolve silver, when undiluted: it will not dissolve gold, platina, iron, zinc, or nickel, unless it be diluted. This is an useful, because a cheap process. Aqua regia made with nitric acid is dear comparatively.

ON ROLLING COPPER INTO PLATES.

The following method of rolling Copper into plates, as practised at the extensive works at Taybach, in Wales, is taken from Donavan's Tour through South Wales and Monmouthshire.

BEFORE the copper is converted into plates or bars, the pig of metal is made red hot, when it is closely beaten together under the hammer, and cut into pieces of the most convenient length for the purpose wanted, by shears moved by a wheel. Again, those pieces are conveyed to the furnace when they become red hot as at first. One

of the pieces is carried at a time to the flatting mill, a machine not much unlike the rolling press of a copper plate printer. The two cylinders are of steel, case-hardened and secured within a frame of iron. A man stands on each side, and while the two cylinders revolve, each in a contrary direction, one of them lifts up the piece of red hot copper with a pair of tongs, and thrusts it between the cylinders, the other man on the opposite side securing it with his tongs as it passes through. This he lifts back again over the upper roller to the first man, who by the assistance of a strong screw, diminishes the distance between the two cylinders, in order to widen and compress the plate still more; when it is conveyed a second time between them. This screw is turned for the same reason every time before the plate passes between the cylinders, and thus by the most simple process imaginable, the plate is gradually reduced as thin and broad as the workmen may desire.

By means of a similar machine, the copper is wrought into bars instead of plates, of any form or thickness, with equal facility. For the latter purpose, the smooth surface of both the cylinders are alike indented with eight, ten, or more distinct grooves, all which differ from each other in width and depth. The series commences with the largest groove, encircling one end of the cylinder; the next in point of size succeeds, and thus they diminish gradually to the other extremity of the series, which terminates with the smallest groove. The piece of copper being heated as before to a fiery redness, the workmen force it between the first or largest groove of the adjusted cylinders, where it receives either the round or angulated form of the groove from the compression of both the cylinders, as readily as wax in a common mould. Should it be necessary, the bar is conveyed in like manner progressively through the second, third, or fourth groove, or

through the whole series, till it is reduced to the thickness wanted, the length being increased in proportion as the bulk diminishes.

The copper, after receiving its proper form in the flatting mills, and cooling, is of a dusky black, or iron colour, and in order to communicate to it that lively hue which is commonly understood to be the true complexion of this metal, the plate or bar is heated again for the last time in a furnace, and when red hot is plunged into a recess filled with a saline liquor,* where it assumes that colour in a few moments, and being withdrawn, the copper is put aside as being finished for exportation.

[3 *Archives*, 14.

To Separate Copper from Silver.

Sir—I intended to have deferred the present communication till such time as I should have it in my power to lay before the public the complete series of experiments in which I have been engaged with regard to the purification of gold and silver. But unluckily I mentioned a few particular circumstances with regard to them, to a man who took it upon him, without my knowledge, to send an account of them for publication to a periodical work. As I understand that work will not appear so soon as your next number, I beg, if you think it worthy of a place, that you will insert the following account of some attempts I have been making to purify the precious metals.

Being much at a loss for the want of a crucible of pure silver for the analysis of some minerals, and as all the usual methods practised for purifying that metal are very troublesome, I set myself to consider the various operations on metals, in hopes of falling on a more simple way

* In Aikin's Chemical Dictionary, it is stated, that this fluid is urine. The redness which the copper thus acquires, is considered by the merchant as one mark of the purity of the metal.

of accomplishing my purpose. At length, I found a process of Pelletier's, which promised to succeed, and mine is merely extending his idea a little further than he did himself.

He was, I believe, employed by the French government to discover an easy way of separating the tin from copper on bell-metal, and the process he gave, is this. Upon the melted bell-metal project black oxyd of manganese in powder, frequently stirring the metal till all the tin becomes oxydated by the manganese. He adds a caution, not to add too much manganese otherwise part of the copper also will be destroyed.

It immediately struck me, that in this way I might be able to oxydate the copper which alloys our silver, and upon making the trial I succeeded completely: I had some impure silver rolled out to about the thickness of a shilling, this I coiled up spirally, and put into a crucible, the bottom of which was covered with black oxyd of manganese. I then added more oxyd till the silver was covered, and all the space between the coils completely filled. A cover was then luted to the crucible, and a small hole left for the escape of oxygen gas. When this had been exposed for a quarter of an hour to a heat sufficient to melt silver, I found the surface of the manganese brown from the loss of oxygen; but, where the silver had been, the whole was one uniform black powder, without the least appearance of metallic lustre, so that I had no doubt, that even the silver was become an oxyd.

I then put the whole contents of the first crucible into a second of a larger size, into the bottom of which I put a quantity of pounded green glass, about three times the bulk of the contents of the first crucible, and luted on a cover as before, to prevent the access of any inflammable substance.

The crucible was then exposed to a heat sufficiently strong to melt the glass very fluid. Upon cooling and breaking the crucible, I found the silver at the bottom perfectly pure, as its oxyd alone could part from its oxygen without the access of some inflammable substance. I find this process answers equally well for purifying gold, and to me it seems to possess some advantages over all the former methods. The materials used are cheap, and a large quantity can be refined as soon and as easily as a small quantity, by merely altering the capacity of the crucible you use.

I tried the same operation on gold and silver in round masses, but found it went on very slowly, and what I scarcely expected, in the first part of the process of oxydating the metals, the remaining metal continued uniformly impure or nearly so, until the whole was oxydated.

I regret that I have been forced to make this matter public, before I could do it in a manner satisfactory to myself. I wished to have given the exact proportions of alloy, manganese, and glass to be generally used, and to have ascertained if there is any truth in the old opinion, that saltpetre melted with gold destroys a part of it. I suppose that idea may have arisen from the oxygen given out by the nitre in a high heat, oxygenating the copper contained in the impure gold, which has been the subject of the experiment.

Since the above was written, I have been informed that this matter has actually been published, but know not in what work. I hope you will still have the goodness to insert this as an *original communication*, as I do not think the person who has published it will have the impudence to call it his own, and as Mr. Kirwan, and other celebrated chemists long ago advised me to publish it, I have already stated my reasons for not following such good advice.

As I have now been forced to appear before the public, I have hopes I shall be able to prevail on some of my friends to commit themselves in the same way, in the confidence that their labours will be found useful to the public.—I am Sir, your's truly,

ANDREW THOMSON.

Banchory, by Aberdeen, May 5th, 1805.

[11 *Nich. Jour.* 125.

Observations on the Metallic Composition for the Specula of reflecting Telescopes, and the manner of casting them: also, a Method of communicating to them any particular Conoidal Figure: with an attempt to explain on scientific principles, the grounds of each Process: and occasional remarks on the construction of Telescopes. By the Rev. JAMES LITTLE.

There are but few things produced by the united effort of mechanical artifice and intellectual labour, which have done more honor to the ingenuity and invention of man, than the reflecting telescope; which has many advantages over any of the dioptrical kind, notwithstanding their improvement by acromatic glasses. It will bear a greater aperture, and may be made to magnify more, (as being more distinct,) in proportion to its length, than the others, as they are at present made; and its dimensions and powers are unlimited. What its excellence is, espepecially the Newtonian construction of it, has been proved by Dr. Herschell, to his own honor, and that of the age, and country, and patronage, which encouraged his labours. Accordingly, the persons, eminent for science and mechanical ingenuity, appear to have felt a peculiar and disinterested pleasure, in contributing to its improvement; and the late discovery of a metallic composition for the mirrors of it, which will bear as high a polish as glass, reflect as much light as glass transmits, and endure al-

most equally well, without contracting tarnish, is a farther encouragement to prosecute its improvement to perfection.

Among others, I had formerly, from admiration at its contrivance, bestowed some attention on the mechanism of this instrument: and, as it would have spared me some expence of time and trials, if any other person had previously suggested to me the hints, which I am to relate, I imagine they will be of use to others, in directing or assisting the course of their labour, in the same pursuit. I had also taken some pains, to understand the merits of the different constructions of this telescope: but, as this enquiry ended in a conviction, that the Newtonian form of it is the most perfect that can be hoped for; (it being the nature of its great author to persevere in his researches, till he had arrived at a complete solution of his doubts, and comprehension of the subject;) so I have only to report what resulted from my experience in the mechanical fabrication of it, as to the method of casting the mirrors, and communicating to them the proper figure.

Before I had heard of the improvements of the Rev. Mr. Edwards, in the composition of the specula for telescopes, I had made many experiments myself with that view; which lead me to give full credit to his report of the superior excellence of that composition which he recommends: because I had found, that the qualities of hardness, whiteness, and indisposition to contract tarnish, necessary to a speculum, could not, by any admixture that I could hit upon, be produced, unless the metal were so highly saturated with tin, as to be excessively brittle; and because I found that this brittleness, however inconvenient in some respects, was necessary to render it susceptible of the highest polish: for no metal yet known, except steel, (which, from its disposition to rust, is unfit for

this purpose,) will take as high a polish as glass will, unless it be more brittle than glass. And indeed this property is common to all substances which we know, that are capable of such polish: they must be very hard, and, as such, brittle; for the polishing powder employed would stick and bed itself in any soft metal, instead of cutting and polishing it.

From the result of my trials, I contented myself with the composition mentioned hereafter, as being in every respect sufficient for the purpose, and inferior to none in whiteness, lustre, and exemption from tarnish: for, as to the addition of silver, I found that, when used even in a very small quantity, it had an extraordinary property of rendering the metal so soft, that I was deterred from employing it: and unless it shall be found that, without this effect, it makes the metal less porous than otherwise it might be, or less frail and brittle, I am certain that it may, in every other respect, be dispensed with. I had no opportunity to try it, in the precise quantity Mr. Edwards recommends, (though I did so before, in very nearly that proportion, since I first saw his memoir on that subject. Sir Isaac Newton made trial of a very small portion of it, and found the same effects from it as I experienced: but it is possible, that, if it were added in the just proportion discovered by Mr. Edwards, it would be an improvement, and useful ingredient, in the composition.*

* Having read somewhere, that zinc and gold made the best speculum-metal, I tried it; and found, that the zinc was sublimed from the gold in fusion, and arose to the top in the crucible forming a white, hard, spongy mass. The metal, called tutanag, is fit for specula, when melted with tin; but I am certain, that what I procured, under the name of tutanag, was a mixture of brass and copper, &c.; for the zinc, in the brass, rose from it, during the fusion, in white flowers.

I must observe here, that a metal, not liable to contract tarnish from the air, is otherwise susceptible of it accidentally: when there happen to be minute holes in its surface, caused by the air, or sand, &c. in casting it. Such cavities will be filled with the dust, or rusty solution of the brass, in grinding; which will, in time, become a sort of vitriol, and act on the contiguous parts of the speculum, producing a canker in it, which will spread in form of a cloud of tarnish, around each cavity. In such a case, to prevent this, I would advise, to lay the mirror, as soon as polished, in warm water, and, after drying, while it remains heated, to rub it over with spirit-varnish, from which it may be cleansed, by a piece of fine linen dipped in spirit of wine. The varnish will remain in the cavities; and, by defending the impurities in them from the action of the air, will probably preserve them from becoming corrosive to the metal.

From numerous experiments, of the qualities of different compositions, made by several persons, it appears, that no combinations, of any other metals or semi-metals, are fit for specula, except those of copper, brass, tin, silver, and arsenic. I tried no semi-metal, except the latter, which whitens copper, and unites intimately with it: because it is stated, in the treatise of the *Art of Assaying*, by the observant and accurate *Cramer;* that all the semi-metals rise in flowers, during the fusion: which would certainly make the metal porous. On this account, I would have rejected the brass, because of the zinc contained in it; but that it seemed to render the composition whiter, and less apt to tarnish, than it would be without it. It will have little tendency to rise in flowers, if the speculum, metal be fused, with the lowest heat requisite, and if the brass be of the best kind; because, in this, the zinc is more perfectly united with the copper, and both are purer. I used, for this purpose, the brass of pin-wire:

and, because the quantity of it was only the one-eighth part of the copper employed, which, I imagined, would receive too fierce a heat, if put alone into the melted copper; I first added to the brass, in fusion, about an equal quantity of the tin, and put the mass cold into the melted copper; supplying afterwards the remainder of the tin, and then the arsenic; the whole being generally in the following proportion: viz. 32 parts best bar copper, previously fluxed with the black flux, of two parts tartar, and one of nitre, 4 parts brass, 16 1-2 parts tin, and 1 1-4 arsenic. I suppose, with others, that, if the metal be granulated, by pouring it, when first melted, into water, and then fused a second time, it will be less porous than at first.

In this process, whatever metals are used, and in what proportions soever, the chief object is, to hit on the exact point of saturation of the copper, &c. by the tin. For, if the latter be added in too great quantity, the metal will be dull-coloured and soft; if too little, it will not attain the most perfect whiteness, and will certainly tarnish. It is too late to discover the imperfections of the metal, after the mirrors are cast and polished; and no tokens given of them (that I know) are sufficiently free from ambiguity. But I observed the following, which proved, in my trials, at first view, indubitable marks of the degree of saturation; and I think it fit to describe them particularly, as they have not, to my knowledge, been noticed by others.

When the metal was melted, and before I poured it into the flask, I always took about the quantity of an ounce of it, with a small ladle, out of the crucible, and poured it on a cold flag; and observed the following appearances:

First. If the metal assumed, in cooling, a lively blue, or purple colour, commonly intermixed with clouds, or

shades of green or yellow; and if, when broken, the face of the fracture exhibited a silvery whiteness, as bright and glistening as quicksilver, without any appearance of grain, or inequality of texture; then the degree of saturation of the metal, with the tin, was complete and perfect.

Secondly. If the surface of the metal became of a dun or mouse colour, and especially if of a brown or red; and when broken, the fracture exhibited a more yellow, or tawny hue, than that of quicksilver; then the quantity of tin in the composition was deficient, and it was necessary to add more.*

Thirdly. If the colour was an uniform dull blue, like lead, where broken, discovered a dull colour, with a coarse grain, like facetts; the due saturation was exceeded, and there was an over proportion of tin in the metal.

These colours would be more distinct, if a small quantity of the metal were cast in a flask, which had been previously smoaked, by a candle, made of resin mixed with tallow in which way I used to prepare the moulds. I attribute the formation of the colours to this: that, as the calx of every metal has its own peculiar colour, so, the heat of the melted mass, calcining some of the particles on its surface, which are in contact with the air, these display the colour of the calces of those ingredients which prevail in the composition. Whence, it may be expected, that, if the copper is the redundant metal, the mass will exhibit a reddish tinge, which is appropriate to

* This can always be done by degrees, and without any trouble, till the point of saturation is found; whereas, if too much tin were added at first, there would be a necessity for melting more copper separately, and repeating the whole process: and different specimens of copper will require different proportions of tin; so that the due quantity can never be known, *a priori*, but on trial only.

the calx of copper; and, if the tin be prevalent, a blueish die ought to appear. Either of these colours, therefore, appearing unmixed, shews the redundance of that metal, to which each belongs. And, as brass, when cast alone, has always a yellow tinge, so, when these three colours are exhibited in a cloud-like mixture, they shew an equality and due proportion of their respective metals in the composition. When too large a mass of the metal is cast together, its intense and lasting heat calcines the surface so deeply, as (when exposed to the air) to obscure the colours; so that a small quantity will best serve to exhibit them.

As to the method of casting the mirrors, it has been directed, to leave the ingate, or superfluous part of the cast, so large, as to contain a quantity of metal, equal to that in the mirror itself; which would occasion a great waste of it, and render it not easy to cast, at once, more than one mirror in each mould; and even this might be done so injudiciously as not to afford security against a miscarriage of the cast. But it will appear, that this great quantity of metal and incommodious manner of casting it, are by no means necessary. However, a judgment cannot be formed, of what may be the safest and most eligible method for casting the mirrors, unless it be considered, what are the circumstances attending this operation, in the case of malleable metals; and how the management of speculum-metal, in this respect, must differ from that of them: since there must be peculiar difficulty in casting, in sand, a metal more brittle than glass.

When any fused metal is poured into the flask, the external parts of it, which are in contact with the mould, congeal and harden sooner than the internal parts, and form a solid shell, filled with the rest of the metal, in a fluid state. This will, consequently, remain in a state of greater expansion, from its heat, than the external crust;

and its particles will, in the act of shrinking as it cools, recede from one another, as being more easily separable, and cohere, on each side, with the particles already fixed and grown solid: by which means a vacuum will be formed in the middle, and this will be gradually filled by the superincumbent metal, which has been later poured in, and remains longer in a fluid state. But, when there is no more metal supplied, the void, which was in this way latest formed, remains unfilled; and then the shell of the metal, adjacent to the vacuum, as yet remaining soft, and unable to bear the weight of the atmosphere, resting on it, sinks, and is pressed down into the vacuum: by which means, a pit or cavity will be constantly and necessarily formed in the face of the cast, in that part of it which was last congealed; which cavity will commonly be larger or smaller, in proportion to the quantity of metal in the cast.

The event will, in this respect, be the same with speculum-metal, as it is, in the case of that which is tough and malleable: only that, as the former, in cooling, arrives sooner at its natural state of hardness and brittleness, its external solid shell will not bend, but break, and fall into the void part under it; and thus form cracks, or abrupt chasms, in the places, where tougher metals would contract only regular depressions. And also, when the body of the cast is small, or the mould is so damp or cold, as to congeal, not only the surface, but the substance, of the cast too soon, and thus prevent a gradual influx of the fluid metal, to keep the central part as distended, as the exterior shell was, when it became fixed; the farther contraction of the interior parts of this brittle, refractory metal, after it has become solid, will be apt to form rents in it, because its substance will not bear extension, without rupture.

It would be an obvious remedy of the above inconvenience, if there could be contrived a reservoir of fluid metal, to descend into the interior part of the cast, and fill up the void made in it, as fast, and as long, as it is forming by the contraction of the metal. Now, this is effected, by having a jet or appendage to the cast, of such a size, form, and position, as will be effectual to retain the metal, composing it, in a state of fluidity ; and also to suffer it to descend into the interior of the cast, until all parts of the same become fixed, and incapable of receiving any farther influx of metal. For thus, all the imperfections, that would otherwise be in the cast itself, will now exist only in the appendage to it, which is a supernumerary part, to be afterwards separated from it. This appendage ought to be of the form of a prism, and as nearly that of a cube, as the operation of moulding it in the sand will permit; for, in this gross shape, the metal in it will be the longer cooling. It should be connected with that part of the mirror, which is uppermost in the flask, and joined to it by a neck, equal in thickness to the edge of the mirror, (but so posited, that the face of the mirror may project a little above it), and, in breadth; about twice the thickness. This neck ought to be as short as possible, i. e. just so as to permit it to be nicked round with the edge of a file, in order to break off the prism from the mirror when cast: for thus the heat of the large contiguous body of the prism will keep the neck from congealing ; which, if it happened, would stop the liquefied metal, in the prism, from running down into the mirror. And, to prevent this, the prism ought not to form directly a part of the main jet or ingate, by which the metal is poured into the flask ; for so the jet would cool sooner than the large mass of the mirror, and bear off the weight of the atmosphere, which ought to press on the fluid metal in the prism underneath, and force it down into the mirror, to fill up all vacuities

in it. Both the prism and the mirror, therefore, ought to be filled by a lateral channel, opening (from the principal ingate) into the top of the prism; which latter should be formed broad and flat, and not taper upward, like a pyramid, lest, by cooling where it grows narrow, it might form a solid arch and oppose the pressure of the atmosphere. When it is fashioned as here directed, and made of a bulk equal to a third or fourth part of the mass of the mirror, or even a fifth or sixth part, when the mirrors are of large size there will ever be found in the top of the prism, after the metal is cast, a deep pit or cavity which contained the metal that had ran down into the mirror, after the outer shell of the mirror and sides of the prism had become solid and congealed; and the mirror itself will be found ferfect, without any sinking or cavity; which could only be formed by an injudicious disposition of the jet or appendage, permitting the metal in it to freeze sooner than the whole mass in the mirror, and thus stopping its descent into it. If several mirrors be cast together, in the same flask, there must be such a separate appendage made to each of them.

In this manner I have (without a failure in any) cast many mirrors of different sizes, and sometimes several of them together in one flask. But very small ones, such as the little mirrors for Gregorian telescopes, cannot be cast in this manner; for their masses being but small, they cool too quickly to receive any additional infusion of metal; and their outer edges, suddenly forming a solid incompressible arch, the central parts, in contracting towards it on every side, separate, and are rent asunder. And this has happened, even when I cast them in brass moulds made red hot: on which account I have been obliged to form them out of pieces of the metal, cast in long thin ingots or bass; which, by nicking them across with a file, could be easily broken into square pieces,

whose corners could be taken off, and rounded in the same manner.

I do not repeat the other precautions to be observed in this process, which have been already so well and sagaciously described by the Rev. Mr. Edwards; but the circumstances above mentioned, a prudent attention to which is in my opinion essentially necessary to the success of it, are not to be collected from any directions published on the subject that are known to me. And though particular artists may, by large experience, arrive at a sufficient knowledge in this matter for their own practice; yet, to render that knowledge general, and to contribute as far as I could to the improvement of this instrument in in any hands, being the design of this essay, I thought it necessary to state the above particulars fully; though I doubt not that these, as well as other matters of moment in the operation, are known to many who chuse not to make them public. Thus the great skill in the construction of the telescope, acquired by Mr. Short, seems not to have been transmitted to any successor.

16 *Nich. Jour.* 30.

I do not insert the rest of this valuable paper, because it relates merely to the method of *grinding* the specula: those who are interested in the construction of optic glasses, will do well to refer to it. I have made Edward's speculum metal, and with a small proportion of silver in it, I think it would be applicable to many other purposes. The polish and the colour are excellent.

In the report of Elias Boudinot, Esq. on the mint 1796, 1797, it is said that the beauty of gold coin is improved by making the alloy two thirds copper, and one third silver.

" *Copper precipitated by Tin.* An intelligent correspondent, Mr. Collard of Birmingham, the proprietor of

a chemical laboratory in that neighbourhood, in which many articles necessary to the arts and manufactures of this kingdom are prepared on a very large scale, has communicated to us a new fact well worthy of the attention of chemists.

"Contrary to the common tables of affinities, he finds that copper may be precipitated from its solution in the sulphuric acid by tin. All that is necessary to the success of the experiment is, that the solution be nearly at the boiling point, or actually boiling, when the tin is put into it. The tin made use of ought to be in filings or in leaf, or reduced to thin fragments by pouring it, when in fusion, into cold water.

"To the enlightened chemist we need not point out the experiments suggested by this new and curious fact, and the important results to which it may ultimately lead, If copper and tin, by a mere difference in the temperature of the solution, may be made mutually to precipitate each other, it is not impossible that the order of affinities with respect to other metals for the different acids may also be inverted by circumstances connected with temperature. Should any such results be obtained, they will be productive of incalculable advantages in many intricate cases of analysis. The different results obtained in apparently similar experiments, by equally accurate chemists, may perhaps have been owing in some cases to the existence of such a law as we now allude to."

24 *Philos. Mag.* 284.

Brazing. The soldering or joining two pieces of iron together by melting brass between the pieces to be joined. Clean well the edges of the iron. Take what is called spelter solder: or finely granulated brass, or brass dust, mix it up with pulverized glass of borax into a consistence by means of water. Smear with it the place to be brazed, and hold it over the flame of a charcoal fire,

without touching the coals, till the brass is melted: or fuse with a blow pipe.

I do not recollect at present, any further communication of consequence on the subject of *Copper*, except the following.

Glazed Copper and Iron Vessels.—A Mr. Hicklin some years ago obtained a patent for glazing iron and copper kitchen utensils; this can be done either with the common composition for Queen's ware (the common yellowish white pottery) or with the other receipts given by Mr. Hicklin, which I give as under: the queen's ware is composed of 3 parts by weight of good clay well ground, and washed, and one part of burnt flint in fine powder; it is glazed with a composition consisting of 100 parts white lead, 25 parts ground flint, and 5 parts ground flint glass, which contains about one fifth of lead.

Hicklin's compositions are these: 6 parts calcined flint, 2 parts white granite, 9 parts litharge, 6 parts borax, 1 part clay, 1 part nitre, 6 parts calx (oxyd) of tin, 1 part potash.

In this, the white granite, probably means the decomposed feldtspar of the granite, such as abounds near Philadelphia and Baltimore: some of the other fluxing ingredients might be omitted, as the potash for instance, but they are not very expensive.

Or, 8 parts calcined flint, 8 parts red lead, 6 parts borax, 5 parts calx of tin, 1 part nitre.

Or, 12 parts white granite, 8 parts borax, 10 parts white lead, 2 parts nitre, 1 part of white marble lime, 1 part clay, 2 parts pearl ash, 5 parts calx of tin.

Or, 4 parts calcined flint, 1 part white granite, 2 parts nitre, 8 parts borax, 1 part white marble calcined (that is, lime), half a part clay, 2 parts calx of tin.

(The calx of tin is made by calcining in with heat exposed to the air; by fusing it with nitre, or by precipi-

tating it from muriat of tin, or by calcining it by digestion with nitric acid. In London there are persons who deal in white enamel, for the use of clock and watch makers, and who make a trade of calcining their tin which is the chief part of the composition; the flux being borax and flint glass, and I believe a little white arsenic.

Either of these formulas, are to be well mixed and then fused. While in fusion they are to be poured out on a clean iron or copper plate, and when cold, ground to a powder, passed through a sieve, again levigated with water, to which mucilage is to be added to keep the powder suspended. With this paste the inside of the vessel is to be smeared: when dry to be again slightly smeared over: then exposed to a heat sufficient to melt the composition; the vessel thus coated must be cooled gradually.

I have used of these vessels with great satisfaction.

T. C.

STARCH.

On the making of Starch. By Mr. JAMES GRAHAM, *of Berwick-upon-Tweed.*

STARCH may be made from a variety of articles:—potatoes, in particular, will yield a considerable quantity; but the great labour attending grinding or grating them down has hitherto prevented any great quantity of starch being made from that vegetable. When the potatoes are grated down, they do not require to be laid in steep to ferment after the manner of flour, but must be immediately strained through a sieve; and if the potatoes are of a good quality, the starch will settle to the bottom almost instantly: indeed the operation of straining after the potatoes are grated down cannot be performed too quickly. The produce, however, even from the best, is far less than most people would imagine; the best potatoes I ever used, only produced 4 or 4½ stones of starch from 40 stones of potatoes.

Potatoe starch is not saleable in the shops, not having so long and firm a grain as starch from flour; but if properly made is preferable to all others for blue-makers, as it melts or dissolves so easily, and incorporates with the colour with far less trouble than any other substance whatever.

When starch is made from flour, the wheat is not ground so small as when intended for sale, but ground with a broader flag or bran, as the meal and starch are found to separate more readily from the bran. When laid in to steep, as much water must be used as to wet completely the whole meal; in three, four, or five days it will ferment, and in a few days more will settle, and all fermentation cease: after this, the stuff is fit to be what is called, washed out.

The common time allowed to steep is fourteen or twenty days: as much depends on the temperature of the weather, the exact time cannot be ascertained; but it is much better to lie a few days longer than to be washed out one day too soon. This operation is performed by the stuff being taken from the vats and put into a strong round basket, which is set across a tub below a pump: one or two men keep going round the basket stirring up the stuff with strong wooden shovels, called stirrers, while another keeps pumping water till all the meal is completely washed from the bran, which is emptied into some convenient place to feed hogs: this operation is continued till the vats are emptied of the whole stuff, at the same time that it is strained through the basket into the tub underneath. As fast as the tub fills, it is taken out and strained through hair sieves into what are sometimes called squares, by others, frames. It is then suffered to rest twenty-four hours, when the water is drawn off the frame by plugs fixed at different depths. A thin stuff is then found to float above the starch, which is taken off by a tray made of a particular form for that purpose: this is called slimes, and is put into a cistern to feed hogs, by being mixed with the bran or grains: fresh water is then pumped into the squares, and the whole is wrought up with the stirrers till it is completely incorporated with the water; it is then strained through a fine silk sieve, and suffered to rest and settle twenty-four hours, when the water is again drawn off, and some more slimes will be found floating, or at least in a loose and unsettled state, on the top of the starch; which being carefully removed, fresh water is again pumped on the starch, and the whole is again wrought up as before; when it is again put through the silk sieve.

It is now suffered to rest for some days,—say four or five,—till the starch is again settled in a very firm state at the bottom of the square. It is necessary to observe, if the starch is wanted to be what is commonly called Poland, that is, with the blue shade; during the last time of putting through the silk sieve, a certain quantity of the very best smalts must be mixed with the starch. If the smalts are very good, 2lb. per cwt. may do, and sometimes 3lb., according to the depth of blue wanted: if the best smalts are not used, however fine the colour may appear when in a damp state, it will entirely fly off in the stove, and leave the starch of a dingey hue.

When the starch is found to be completely settled, the water is again drawn off; and if any more slimes are still on the top they are taken off as before, and the starch is now fit for boxing. It is necessary to observe, that the slimes taken off after the starch has been put through the silk sieve are not put into the hog-wash, but are either mixed with some other operation, or again wrought up with water and strained through the silk sieve; when a considerable part of them will be tolerably good starch.

The boxes may be made of different sizes; but they are commonly about four feet long, six inches deep, and twelve inches broad, and are bored full of holes, so that any remaining water may drain from the starch. Thin canvass is cut in such length and breadth as to line all the inside of the box, the intention of which is to bring the starch clean from the box after the water is fully drained.

The boxing is performed by digging the starch out of the square with a spade or shovel, and filling the boxes. The length of time for the starch being in the boxes can only be ascertained by the starch coming to a hard solid body, which is sometimes sooner and sometimes longer. The starch is then taken from the boxes by turning them bottom uppermost on a table or dresser; it is then broken into pieces about four or five inches square, by laying a ruler or round piece of wood underneath the starch, giving the upper side a cut across with a knife; when a small press of the hand will break the starch into such pieces as are designed.

It is then set upon soft bricks, that is, bricks which have been only half-burned in the kiln: the intention of this is to suck the water out of the starch; which if not done before it is put into the stove, it is apt to dry into various hard substances called hamy,

which will not melt when it comes to be used; so that it will not answer for blue-makers, nor for the purpose of the laundry.

When sufficiently dried on the bricks it is put into the stove, (which is nearly the same as a sugar-baker's,) where it remains some time: the duration must depend on the judgment of the maker, and the degree of heat in the stove. It is then taken out and set on a table or dresser, when all the sides are carefully scraped or pared with a thin knife; after which, it is tied up in paper the same as we see it in the shops; when it is again returned into the stove, and continued with a regular heat night and day till completely dry: it requires some days, but the length of time can only be ascertained by an experienced maker.

It may be necessary to observe, that from the first laying in the meal to steep, till the last operation of taking from the stove to be weighed, the manufacture is constantly under the survey of one or more officers of excise.

19 *Philosophical Magazine*, *p.* 166.

MANURES.

A PLANT contains *water;* that is hydrogen and oxygen: *Carbon*, that is charcoal: *Hydrogen*, usually combined with the charcoal, and giving out light and flame when the vegetable is burnt, as carburetted hydrogen: *Vegetable acid*, that is carbon, hydrogen, and oxygen; *Potass*, whence derived or how formed I know not; *earths and salts* in small and accidental quantities, deposited as I apprehend from the fluids taken up by the roots: these are not found uniformly, either in kind or quantity, and they vary in both respects with the nature of the soil and of the manure. Thus, the calcareous earth found in potatoes, and the siliceous earth found in the scouring flag, in the straw of grain, in the joints of reeds and canes, &c. can hardly be considered as essential parts of vegetable substance, any more than the nitre in borage, in tobacco, &c. which, if the vegetable organization cannot decompose, must exist deposited in its proper form.

Hydrogen, oxygen, and carbon then, are the principal component parts of vegetables: even potash seems not essential to all vegetables, inasmuch as the resinous plants contain it in very small

proportions indeed. Thus the ashes of pine, are worthless in our families.

The roots of a plant, do not seem capable of taking up and conveying to the sap vessels, any solid substance. Hence, manures of pabulum can only consist of such substances as being composed of hydrogen, oxygen, and carbon, all three, or any two of them, are capable of watery solution, and also of being decomposed by the powers of vegetable organization.

Of these three principles, carbon is the first in importance, as forming so large a part of the solid substance of a plant. But the solution of carbon in water cannot be effected alone, and it seems to have remained as a desideratum in chemical agriculture, till the experiments of Arthur Young, Esq. of which I am about to give an account.

In the 43d volume of the Annals of Agriculture, p. 433, there is a paper by the editor, A. Young, Esq. on the effect of sixty-four mixtures of substances intended as manures, on plants of barley. The mixtures to be sure are not very scientifically combined, but there is no material objection that I see, to the general results of the experiments. They were made in 1803. The paper is long, I shall therefore extract only the result: premising, that No. 16 consisted of half an ounce of powdered charcoal, and half an ounce of powdered pearl ash, in three quarters of a pint of water, well shaken for six hours.

No. 31 was half an ounce cut straw steeped in putrid stable urine for three days.

No. 64 is nothing but nitre with excess of acid; being equal weights of pearl ash and aqua fortis, in double the weight of water.

His notion that the good effect of muriat of soda, common salt, is to be attributed to the soda alone, is manifestly owing to imperfect notions of chemistry, and physiology. The paper is closed by the following observations, which I present to the reader.

"*Observations.*—That the result may appear in a more simple manner, I shall throw the numbers into the order of merit, adding together the number of grains and the weight of the straw.

No.	16	Pearl ash and charcoal fluid - -	715
	31	Straw steeped three days - -	473
	19	Holkham loam - - -	320
	64	Pearl ash and spirit of nitre - -	296
	60	Soda - - - -	291

No. 41	Soot - -	289
32	Chalk and salt - - -	269
35	Gypsum - - - -	244
61	Bay salt - - - -	212
22	Salt - - - - -	196
27	Straw steeped 15 hours - -	193
21	Salt - - - - -	188
25	Straw steeped 3 hours - -	188
17	Fleg loam - - - -	185
33	Chalk and salt - - -	177
37	Do. gypsum and spirit of hartshorn	177
63	Magnesia - - - -	177
24	Salt - - - -	167
14	Pearl-ash - - -	167
36	Chalk and gypsum - - -	164
23	Salt - - - -	151
59	Nitre - - - -	148
15	Pearl-ash and charcoal dry - -	146
34	Chalk - - - -	145
35	Gypsum - - - -	144
28	Spirit of hartshorn - - -	142
62	Iron filings - - -	140
26	Dry straw - - -	139
20	Salt - - - -	136
13	Charcoal - - - -	128
57	Bottle 5 - - -	123
44	Salt - - - -	105
39	Soot - - - -	96
2	Spirit of wine - - -	95
29	Spirit of hartshorn - - - -	93
8	Bottle No. 2 - - -	92
43	Salt - - - -	92
40	Soot - - - - -	88
6	Bottle No. 1 - - -	87
42	Gypsum - - -	84
54	Chalk and hartshorn - -	82
47	Gypsum - - - - - -	79
52	Bottle No. 5 - - -	78
11	Ditto No. 4 - - -	78
4	Spirit of wine - - -	77
55	Bottle No. 5 - - -	76
38	Chalk and spirit of wine - - -	74

No. 30	Spirit of hartshorn - -	73
50	Spirit of wine - - -	68
56	Charcoal and spirit of hartshorn - -	63
49	Spirit of wine - - - - -	63
3	Spirit of wine - - - -	60
1	No manure - - - - -	57
9	Bottle No. 2 - - - -	55
7	Ditto No. 1 - - - -	54
12	Bottle No. 1 - - - -	48
5	Spirit of wine - - - - -	46
10	Bottle No. 4 - - - - -	28
58	Ditto No. 5 - - - -	28
45	Salt - - - - - - -	26
53	Gypsum and bottle No. 3 - - -	25
48	Bottle No. 5 - - - -	17
18	Poor sand - - - - -	11

Remark I. If this experiment had ascertained no more than the solubility of charcoal in water by means of pearl-ash, the time employed would not have been lost. Ingenhouz says, it is totally insoluble in water. Mr. Davy however knows better—he observes, that hot soap-lees will dissolve *some;* and that potash and pearl-ash have *some effect* in rendering charcoal soluble in water. *(Lectures).* Darwin hints at it (240). Dr. Thompson, in his Chemistry, speaks of its probability. *It is not improbable.* Senebier, that pure alkalis dissolve *a small quantity; but not when combined with acids.* III. 155. In another passage *it is insoluble in water, and the alkalies alone have the power of dissolving some particles.* III. 57. From reading these and other passages, and from Mr. Kirwan declaring that to discover the means of rendering charcoal soluble in water, was the great desideratum respecting manures, I concluded that the result was at least very doubtful—but of such complete success, I had no comprehension. It appears that mixed in water, and applied in such a loam, the solution, effective as a manure, takes place; as the pearl-ash alone, and the charcoal alone, (though both good manures) have an effect far inferior.

II. That straw steeped in urine should act powerfully is not surprising; but I did not expect that dry straw would have had the effect of more than doubling the fertility of the soil. Many reflections relative to the application of dung in a fresh or rotten state,

will occur to the reader on this fact. The superiority of No. 30 to 31 in the turnips is remarkable, and shews, that however powerful urine is for one crop, its effect quickly goes off.

III. The result of the several applications of common salt is remarkable. Chalk and salt have an uncommon effect, and from the soda alone having so great a power, it seems evident that in the composition of muriat of soda, it is the soda to which we are to attribute the benefit. The various portions of salt tried (for the inquiry is particularly interesting), and their general result, do not seem to permit any doubt of its efficacy as a manure.

The largest quantity applied, having the effect in the turnips of counteracting a great drought, is remarkable.

IV. The nitrate of potash, whether in a state of solution or solid, has a great effect, but in the former case much superior to the latter.

V. In every application sulphat of lime is beneficial; the single exception of No. 53 is so complex, that it does not merit attention, especially as the quantity of spirit of wine was large.

VI. In the experiments I made many years ago, spirit of wine was almost uniformly mischievous or useless. I had reflected often on a result which was so contrary to all expectation, and concluded that I must have applied the substance in too large quantities. This year I lessened them considerably; and the result is much more favourable: but here one tea-spoonful is better than four; and half and quarter better than three. However, its being beneficial in five cases out of six, shews that it is an inquiry which merits further prosecution.

VII. Spirit of hartshorn appears to advantage, and as the three pots No. 28, 29, and 30, are in the succession of diminished quantities, it shews that the smallest applied might have been too great for the first crop.

But I forbear adding more remarks—here are too many, for this is more properly the readers' work, whose conclusions may be very different from mine."

I think this set of experiments may reasonably be pursued; and the effect of charcoal dissolved in alkali in various proportions as well with heat and without, be usefully compared both as to effect and economy. T. C.

BRICKS.

I HAVE already treated this subject in my last number: but considering it of great importance, as well as the making of mortar, which I shall treat of probably in my next, I have carefully read over Bergman's essay *de laterum coctione rite instituenda*, Op. vol. 4. p. 336, and the article Bricks in Rees's and in the Edinburgh (Brewster's) Encyclopædia. I shall therefore copy the latter article, adding some further observations of my own.

BRICK, a kind of facitious stone, made of argillaceous earth, formed in moulds, and baked in kilns, or dried in the sun.

This substance is now in very common use as a material for building; and its importance, in many cases, as a substitute for stone, is generally acknowledged. It is lighter than stone, and not so subject to attract damp and moisture; and from the quantities that are now made in Britain, its manufacture has become a considerable object of revenue to the state.

The art of brick making consists chiefly in the preparing and tempering of the clay, and in the burning of the bricks; and as the quality of the ware depends very much upon the right performance of these operations, we shall present our readers with a short sketch of the general process of this manufacture. The earth proper for making bricks is of a clayey loam, neither abounding too much in argillaceous matter, which causes it to shrink in the drying, nor in sand, which renders the ware heavy and brittle. As the earth, before it is wrought, is generally brittle and full of extraneous matter, it should be dug two or three years before it is used, that, by being exposed to the action of the atmosphere, it may be sufficiently mellowed and pulverised, and thus facilitate the operation of tempering. At any rate, it should always have one winter's frost; but the longer it lies exposed, and the more it is turned over and wrought with a spade, the better will be the bricks.

The tempering of the clay is performed by the treading of men or oxen, and in some places by means of a clay mill. If the operation be performed by treading, which is the common way, the earth is thrown into shallow pits, where it is wrought and incorporated together until it is formed into a homogeneous paste, which is facilitated by adding now and then small quantities of

water; but the less water that is used, the substance of the clay will be more tough and gluey, and consequently the bricks will be smoother and more solid. This operation is the most laborious part of the process; but it is of essential importance, and therefore ought to be done well; for it is to the negligence of the manufacturers in this respect, that we are to attribute the bad quality of our modern bricks, which are often light and spongy, and full of cracks Whereas, if the clay be properly tempered, they are hard, ponderous, and durable; much stronger and better fitted for every kind of building, than those made in the common way. This will appear very evident from the following experiment of M. Gallon. Having taken a quantity of brick-earth, tempered in the usual way, he let it remain exposed to the air for seven hours, and then caused it to be moistened and beaten for the space of half an hour: the next morning the operation was repeated; and in the afternoon the clay was again beaten for fifteen minutes more; making the whole additional labour an hour and a quarter. The bricks made of this earth being dried in the air for thirteen days, and burned along with the rest without any particular precautions, were found to be not only heavier than common bricks, but also very different in strength; for on placing their centre on a sharp edge, and loading both the ends, M. Gallon found, that while it took a weight of 65lb. at each end to break them, other bricks were broken by the weight of only 35lb. The improvement in the quality of the article thus far exceeds the additional labour; and none would hesitate to give an additional price, since both the value and the comfort of our dwellings depend so much on the quality of the materials of which they are constructed.

The next part of the process is the moulding of the bricks. This is a very simple operation, and requires very little skill, unless it be to make the greatest number in the shortest time; and the day's labour of a handy workman, employed from five in the morning until eight at night, is calculated at about 5000. The clay is brought to the moulder's bench in lumps somewhat larger than will fit the mould. The moulder, having dipt his mould into dry sand, works the clay into it, and with a flat smooth stick strikes off the superfluous earth. The bricks are then carried to the hack, and there ranged with great regularity one above the other, a little diagonally, in order to give a free passage to the air. The hacks are usually made eight bricks high; and wide enough for two bricks to be placed edgewise across, with a passage between

the heads of each brick. In fine weather a few days are sufficient to make them dry enough to be shifted; which is done by turning them, and resetting them more open; and in six or eight days more they are ready for the fire.

Bricks in this country are generally baked either in a clamp or in a kiln. The latter is the more preferable method, as less waste arises, less fuel is consumed, and the bricks are sooner burnt. The kiln is usually 13 feet long, by 10½ feet wide, and about 12 feet in height. The walls are one foot two inches thick, carried up a little out of the perpendicular, inclining towards each other at the top. The bricks are placed on flat arches, having holes left in them resembling lattice-work; the kiln is then covered with pieces of tiles and bricks, and some wood put in, to dry them with a gentle fire. This continues two or three days before they are ready for burning, which is known by the smoke turning from a darkish colour to transparent. The mouth or mouths of the kiln are now dammed up with a *shinlog*, which is pieces of brick piled one upon another, and closed with wet brick earth, leaving above it just room sufficient to receive a faggot. The faggots are made of furze, heath, brake, fern, &c. and the kiln is supplied with these until its arches look white, and the fire appears at the top; upon which the fire is slackened for an hour and the kiln allowed gradually to cool. This heating and cooling is repeated until the bricks are thoroughly burnt, which is generally done in 48 hours. One of these kilns will hold about 20,000 bricks.

Clamps are also in common use. They are made of the bricks themselves, and generally of an oblong form. The foundation is laid with *place* bricks or the driest of those just made, and then the bricks to be burnt are built up, tier upon tier, as high as the clamp is meant to be, with two or three inches of *breeze* or cinders strewed between each layer of bricks, and the whole covered with a thick strata of breeze. The fire-place is perpendicular about three feet high, and generally placed at the west end; and the flues are formed by gathering or arching the bricks over, so as to leave a space between each of nearly a brick wide. The flues run straight through the clamp, and are filled with wood, coals, and breeze, pressed closely together. If the bricks are to be burnt off quickly, which may be done in 20 or 30 days, according as the weather may suit, the flues should be only at about six feet distance; but if there be no immediate hurry, they may be placed nine feet asunder, and the clamp left to burn off slowly. Coke has been recommended as a more suitable fuel than either coal or wood.

for this manufacture, both with regard to the expence, and the proper burning of the bricks; for if this substance be applied, the flues or empty places of the pile, as well as the strata of the fuel, may be considerably smaller; which, since the interference of the legislature with regard to the measurement of clamps, is no small consideration; and as the heat produced by coke is more uniform and more intense than what is produced by the other materials, the charge of bricks has a better chance of being burnt perfectly throughout, so that the whole saving may be calculated at least at 32 per cent.

Mr. Goldham observes, that bricks will have double the strength if, after one burning, they be steeped in water and burned afresh. "The excellency of bricks," says Mr. Malcolm, in his *Compendium of Modern Husbandry*, "consists chiefly in the first and last operations—in the tempering of the clay, and in the burning of the bricks; and as every man who has occasion to use bricks, whether on his own estate, or on that of his landlord, cannot but be sensible of the great value of a perfectly dry house; and, as it is impossible a house can be dry if bricks are used which are insufficiently burnt, he will do well to consider whether it will be more advantageous to him in the end, to make use of the very best hard sound bricks, be the colour of them what they may, and be the cost of them what they will. Such bricks are easily known by their sound, and by their striking fire with steel." For a more minute account of the various processes of brick-making, we must refer our readears to that author, from whom much of the preceding information has been extracted.

Bricks are made in various forms; but those which are made for sale, and are in common use for building, are required, by act of parliament, to be not less than 8½ inches long, 2½ thick, and 4 inches wide. There are also square bricks, for pavement or facing walls; and cutting bricks, which are used for arches over doors and windows, being rubbed to a centre, and guaged to a height. Various improvements, however, have of late been made in the moulding of bricks; and as the use of this article is daily becoming more prevalent, they are now formed so as to suit almost every purpose in building. Among these improvements, the patent bricks of Mr. Cartwright deserve particular attention. These bricks are formed with a groove down the middle, a little more than half the width of the side of the brick, leaving two shoulders, each of which will be nearly equal to one half of the groove. When these bricks are laid in courses, the shoulders of

the first course fit into the grooves of the second, and the shoulders of the second fall into the grooves of the first, thus forming an indented line of nearly equal divisions. The grooves, however, ought to be somewhat wider than the two adjoining shoulders, to allow for mortar, &c. The construction of these bricks is perfectly simple; but the principle will be preserved, in whatever form of indenture they may be made to lock into, or cramp each other. Brick walls, constructed upon this principle, require no bond timber; one universal bond connecting the whole building, which can neither crack nor bulge out without breaking through the bricks themselves. This invention is also particularly useful in the construction of arches; and when employed for this purpose, the shoulders of the bricks and the sides of the grooves should be radii of the circle, of which the intended arch is a segment. It is, however, recommended, that if the arch be particularly flat, or applied in situations which do not admit of end walls, to have the shoulders dove-tailed, to prevent the arch cracking across, or giving way edgewise. In forming an arch, the bricks must be coursed across the centre, and a grooved side of the bricks must face the workmen. The bricks may be either laid in mortar, or dry, and the interstices afterwards filled up by pouring in lime-putty,* Paris plaster, or any other convenient material. The obvious advantages of arches constructed upon this principle, are, that the same centre, which, whatever be the breadth of the arch, may be in no case many feet wide, may be regularly shifted as the work proceeds; and as they have no lateral pressure, they require no abutments to prevent their expanding at the foot, nor any weight upon the crown to prevent their springing up. They may be laid upon a common perpendicular wall, and if used in the construction of common buildings, they will not only preclude the necessity, and save the expence of timber, but will also afford an absolute security against the possibility of fire.

A new invention in the formation of bricks, by M. Legressier, has lately been announced in the *Archives des Decouvertes et des Inventions Nouvelles, pendant l'annee* 1809. The principle, however, is merely that of Mr. Cartwright's, followed out to a greater extent than has perhaps ever been done in this country. M. Legressier proposes, that the bricks should be formed in seven different moulds, according as they are to be placed in the middle or on the exterior of the walls; in the bottom or on the top; in the arches or in the corners: and by the proper disposition of these bricks in the building, every pressure, either longitudinally

* Grouting.

or laterally, is resisted, in proportion to the strength of the indentures by which they are locked together.

Besides the place bricks and grey and red stocks, which are used in common building, there are marle facing bricks, cutting bricks, fire bricks, and floating bricks. The first of these are of a fine yellow colour, hard and well burnt; they are made in the neighbourhood of London, and are used in the outside of buildings. The cutting bricks are made of the finest kind of marle; and, as we have already observed, are employed in the construction of arches over windows and doors. Fire bricks, sometimes called Windsor bricks, because an excellent kind of them are made at Hedgesley, a village near Windsor. They contain a large proportion of sand, and will stand the utmost fury of fire, and are consequently used for coating furnaces, and lining the ovens of glass-houses. Clay for fire bricks is got at most great collieries, but particularly at Stourbridge, which produces the best clay for this purpose in England. Floating bricks are a very ancient invention: they are so light as to swim in water; and Pliny tells us, that they were made at Marseilles, at Colento in Spain, and at Pitane in Asia. This invention, however, was completely lost, until M. Fabbroni published a discovery of a method to imitate the floating bricks of the ancients. According to Posidonius, these bricks were made of a kind of argillaceous earth, which was employed to clean silver plate. But as it could not be our tripoli, which is too heavy to float in water, M. Fabbroni tried several experiments with mineral agaric, guhr, lac-lunæ, and fossil meal, which last was found to be the very substance of which he was in search. This earth is abundant in Tuscany, and is found near Casteldelpiano, in the territories of Sienna. According to the analysis of M. Fabbroni, it consists of 55 parts of siliceous earth, 15 of magnesia, 14 of water, 12 of argil, 3 of lime, and one of iron. It exhales an argillaceous odour, and when sprinkled with water throws out a light whitish smoke. It is infusible in the fire, and though it loses about an eighth part of its weight, its bulk is scarcely diminished. Bricks composed of this substance, either baked or unbaked, float in water; and a twentieth part of argil may be added to their composition without taking away their property of swimming. These bricks resist water, unite perfectly with lime, are subject to no alteration from heat or cold, and the baked differ from the unbaked only in the sonorous quality which they have acquired from the fire. Their strength is little inferior to that of common bricks, but much greater in proportion to their weight; for M. Fabbroni found, that

a floating brick, measuring 7 inches in length, 4½ in breadth, and one inch eight lines in thickness, weighed only 14¼ ounces; whereas, a common brick weighed 5 pounds 6¾ ounces. The use of these bricks may be very important in the construction of powder magazines and reverberating furnaces; as they are such bad conductors of heat, that one end may be made red hot, while the other is held in the hand. They may also be employed for buildings that require to be light; such as cooking places in ships, and floating batteries, the parapets of which would be proof against red hot bullets. The turrets which were raised on the ships of the ancients, says M. Fabbroni, were perhaps formed of these bricks; and perhaps they were employed in the celebrated ship, sent by Hiero to Ptolemy, which carried so many buildings, consisting of porticoes, baths, halls, &c. arranged in mosaic, and ornamented with agates and jasper.

Bricks appear to be of the highest antiquity; and, as we learn from sacred history, the making of them was one of the operations to which the children of Israel were subjected during their servitude in Egypt. The bricks of the ancients, however, so far differed from ours, that they were mixed with chopped straw in order to bind the clay together, and instead of being burned were commonly dried in the sun. Vitruvius recommended, that they should be exposed in the air for two years before they were used, as they could not be sufficiently dry in less time; and by the laws of Utica, no bricks were allowed to be used, unless they had lain to dry for five years. From Dr. Pocock's description of a pyramid in Egypt, constructed of unburnt bricks, it appears that the Egyptian bricks were nearly of the same shape as our common bricks, but rather larger. Some of those he measured were 13½ inches long, 6½ broad, and 4 inches thick; and others 15 inches long, 7 broad, and 4¾ thick. The bricks used by the Romans were in general square; and M. Quatremere de Quincy observes, that in his researches among the antique buildings of Rome, he found them of three different sizes. The least were 7½ inches square, and ½ thick; others 16½ inches square, and from 18 to 20 lines in thickness; and the larger ones 22 inches square, by 21 or 22 lines thick. Among the celebrated buildings of antiquity, constructed of brick, were the tower of Babel, and the famous walls of Babylon, reckoned by the Greeks among the wonders of the world; the walls of Athens, the house of Crœsus at Sardis, and the walls of the tomb of Mausolus. The paintings, which were brought from Lacedæmon to Rome, to ornament the Comitium in the

edileship of Varro and Murena, were cut from walls of brick; and the Temple of Peace, the Pantheon, and all the Thermæ, were composed of this material. The Babylonian bricks, which are in the possession of the East India company, and upon which Dr. Hayes has lately favoured the public with a dissertation, are inscribed with various figures and characters, and are supposed by some to be a part of that brick work, upon which Pliny tells us that the Babylonians wrote the observations which they made of the stars for seven hundred and twenty years.

To the above article I would add the following remarks:

1st. The floating bricks therein mentiond, I understand are made by an admixture of pumice dust with the clay.

2d. It is worth while to try clay intended to be used as brick earth. If it contain coarse sand, it ought by all means to be washed, that the small stones may subside: indeed washing and grinding clay, as the common potters do, would be a great improvement on the quality of brick earth.

3d. It should be tried if it contain small particles of limestone; for if it do, the fire will blister and crack the brick by driving out the carbonic acid of the limestone. This may be done by boiling an ounce or two of the clay taken from separate parts of the bed, with a mixture of half water and half spirits of salt, or muriatic acid, which in an hour's time will dissolve the limestone, and this can be separated or thrown down by saturating the acid with pearl ash. The sand can be separated from the clay, by repeated ablution and subsidence.

4thly. Where bricks approaching to porcelain are wanted for particular purposes, the clay should be freed from coarse particles by washing, and mixed with some fine sand and lime. Clay 1 part, lime 1 part, and sand two or three parts will make a mixture that will enter into half fusion in a brick kiln.

5thly. No more sand should be added to brick earth in a common way, than is sufficient to prevent too great a contraction of the clay by the fire.

6thly. Too sudden a fire warps the bricks by the violent extrication of the steam: and too violent a fire is apt to make them run together. Where the expence is not an object, a brick twice burnt, is excellent. I have already mentioned in this work, what I wish potters would notice, that I have never seen the coarest common pottery that by a second gradual and continued burning,

might not be converted into *stone ware*. I have done this repeatedly.

7thly. If the bricks are required to be glazed externally, it can be best done by throwing a bushel of common salt into a kiln of bricks while at their greatest heat, and stopping the top of the kiln.

8thly. The best bricks are made of well burnt clay containing but a small proportion of fine sand. Turning up the earth in the autumn, to expose it to the winter's frost—well working it in the spring before it is moulded—gradual and continued burning in the kiln or clamp, are all of them absolutely essential to a good brick: few of these requisites are usually well performed.

The legislature in England has often interfered in the manufacture of bricks; and considering how much the health of the inhabitants of large towns, depends upon the goodness of bricks, especially in such a climate as England, I am not much inclined to find fault with this interference. By 12 Geo. 1. ch. 35. earth or clay designed for bricks made for sale, shall be dug and turned once at least between the first day of November and the first of February; and not made into bricks till after the first day of March: nor shall any brick be made for sale, but between the first day of March and the 29th of September. But the 10 Geo. 3. ch. 49. earth may be dug at any time of the year, provided such earth be turned once before it be made into brick. By stat. 3. Geo. 2. ch. 22. not more than 720 bushel of sea coal ashes screened through a half-inch screen, shall be mixed with the earth of 100,000 bricks. By 17 Geo. 3. ch. 42. all bricks made for sale shall, when burned, be not less than $8\frac{1}{2}$ inches long, $2\frac{1}{2}$ inches thick and 4 inches wide.

From the want of breeze, or the small cinders of sea coal ashes, more fuel and longer time, are required to burn bricks in this country than in England. The clamps near Philadelphia usually contain about 50,000 bushels; 40 by 40, and 32 high: half a cord of wood is allowed to 1000 bricks: the burning of a clamp takes about a week. Near London, the clamps usually contain 100,000, and the burning last about a fortnight.

9thly. I weighed two bricks that had long been kept in a room in the college here and were perfectly dry. They weighed $10\frac{1}{2}$lb. Immersed in water for an hour they weighed 11lb.

T. C.

OHIO FALLS.

The following method of improving the Ohio Falls, is so applicable to similar falls, that I requested it of Mr. Dowers, the proposer. (See the plate.)

AAAA represents the Ohio river at the falls.

BB a part of the Indian Shute, 60 feet wide, and walled three feet high.

CCCC tributary dams, which turn their waters into the shute at an angle in opposition to the current. They are formed of stone and collect their water from the various separate or waste streams that pass down the falls on each side.

DDDD are openings in the side wall of the shute to receive the water from the tributary dams. They oblige the water to enter it at an angle in opposition to the current.

EFGH are ring bolts fixed at the bottom of the shute to fasten haussers to—to assist boats to ascend.

HH the lowest point of the tributary dams, raised about six inches higher than the openings D, which turn their waters into the shute.

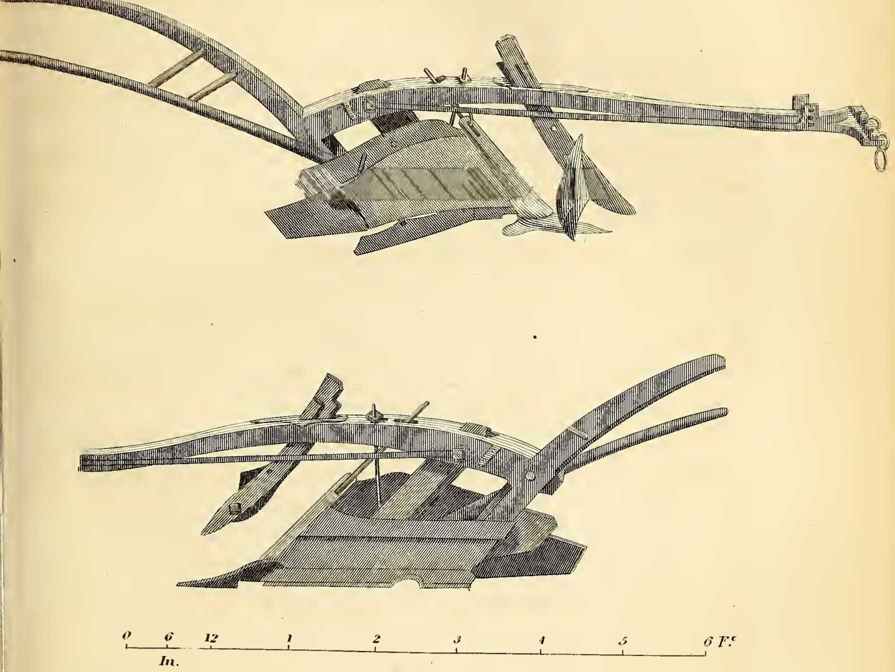
EXPLANATION.

The above explanation relates to a plan for improving the passage of the falls of the Ohio without the aid of a canal and locks, which would be extremely expensive and the benefit at least doubtful. The plan proposed, it is believed, will answer the object as effectually and at a very small expence, comparatively speaking.

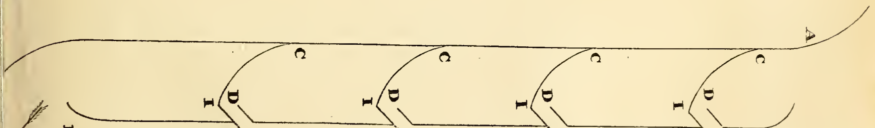
This plan supposes the improvement of the Indian shute, although it may perhaps be adviseable to make an entire new cut from the head to the foot of the falls, but this will depend on the judgment of the engineer. But whether the shute is used as a new channel, the principle and mode of arrangement, is the same. The channel, whether a new shute or the old, should be a regular inclined plane from the head to the foot of the falls; and the stone which is dug out, should be used to line the sides, to keep the water within it. A wall three feet higher than the bottom of the channel is amply sufficient. In order to understand the use of the lateral dams, let us suppose such a channel finished from the top throughout, and the water entering the upper end three feet deep and sixty feet broad, experience and reflection will

Mr. Ducket's Skim Coulter Plough.

which gained the **Premium** *given by*
His Grace *the* **Duke of Bedford.**



Method of navigating the rapids of a River by Mr. Dowers.



C. TIEBOUT SC.

shew us that the descending water will not long preserve the depth of three feet, but will descend so rapidly as in a little time and before it reaches the bottom, be reduced to the depth of a few inches; this consequence uniformly attends water which passes over an inclined plane without obstruction. The rapidity, therefore, and want of depth, would make it of little use. To obviate this in a fall like the Ohio, which passes such a quantity of water, is easy. For having occasion but for a part of it in the first instance, the residue is suffered to move on, and is drawn in from time to time as you have need of it. If it was all compelled to enter the sluice at one time, it would create a fall at the upper end, besides overflowing your shute or channel. These lateral or tributary dams are therefore introduced, in the first place, to check the rapid descent of the water, and to keep up an adequate supply: the first it accomplishes by entering the channel at an angle in opposition to the current; the other by the quantity of water which it adds to it. At what distance those lateral dams might admit of being separated, and yet keep up the requisite supply, must depend on several considerations; but, it is evident, that they cannot be too close together, because the lower end of the dam at ‡ is but little higher than the wall of the shute, and discharges its water over, it if the shute is full, and by that means supplies the dam next below it, if it should require it, which also acts in like manner in its turn. These dams, however, are formed with but little trouble, nature having in all such falls, in a great measure, prepared them to your hand in the various curves and indenting of the rocks; nor is it at all necessary that they should be made with the regularity of the drawing—all that is necessary being to compel it to enter your channel at certain distances by a rough but substantial obstruction at any convenient point. And so easy is this done, that I have seen in the Susquehanna a counter current of more than a quarter of a mile, formed by a dam of loose round stones; the current running directly opposite to the natural course of the stream and almost as rapidly. These counter currents of the tributary dams will so check the velocity of the current in the shute that I make not the least doubt, that if it should be executed on this plan, of loaded boats being able to ascend with perfect ease.

With the aid of a small steam boat, which should avail itself of the ring bolts placed at certain distances along the shute, and, after joining them, draw after it successive a loaded boat. I should make no doubt of its ascending the falls with 100 tons.

BLEACHING: WITH A PLATE.

The plate to which this refers was sent to me some time ago, but not meaning to take up the subject of bleaching yet, I omitted it. However, as it is entitled to insertion, and I am obliged to the correspondent who sent it, I insert it now and shall refer to it hereafter.

AA The machinery to agitate the lime-water within the cask in which it turns round. BB The Still holding the materials.—1, 2, 3, 4, 5, 6, 7 places made air tight with water, to prevent the escape of the gas.

The following paper (which confers equal honour on king George III. and Arthur Young, and the plate that accompanies it,) will give my readers an idea of a genuine, thorough bred Merino Ram.

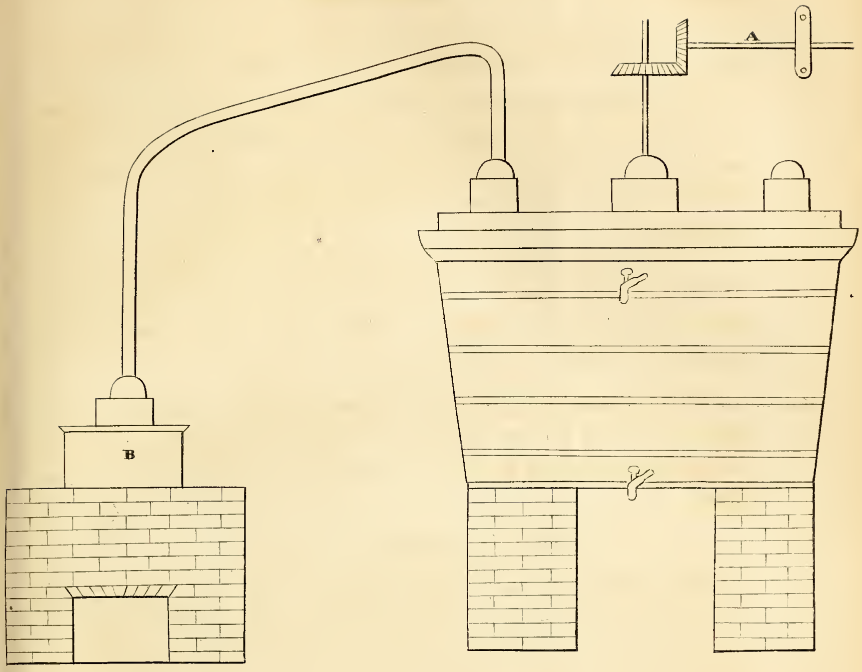
DON. A MERINO RAM, &c.

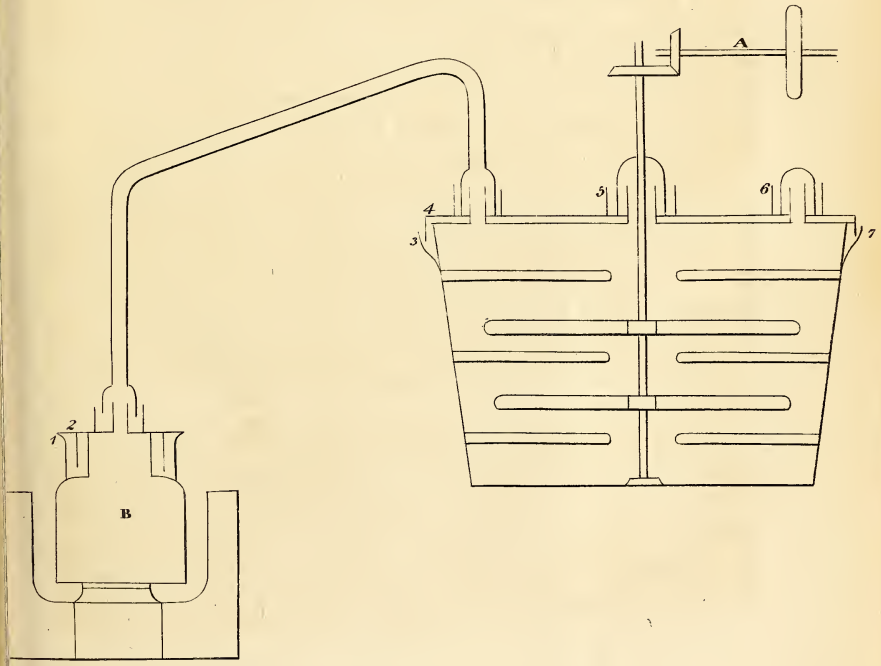
How many millions of men are there that would smile, if I were to mention the sovereign of a great empire giving a ram to a farmer, as an event that merited the attention of mankind: the world is full of those who consider military glory as the proper object of the ambition of monarchs; who measure regal merit by the millions that are slaughtered; by the public robbery and plunder, that are dignified by the titles of victory and conquest, and who look down on every exertion of peace and tranquillity, as unbecoming those who aim at the epithet *great*, and unworthy the aim of men that are born the masters of the globe.

My ideas are cast in a very different mould; and I believe the period is advancing, with accelerated pace, that shall exhibit characters in a light totally new; that shall rather brand than exalt the virtues hitherto admired; that shall place in the full blaze of meridian lustre, actions lost on the mass of mankind; that shall pay more homage to the memory of a prince that gave a ram to a farmer, than for wielding the sceptre—obeyed alike on the Ganges and the Thames.

I shall presume to offer but one other general observation:—when we see HIS MAJESTY practising husbandry, with that warmth that marks a favourite pursuit;—and taking such steps to diffuse a foreign breed of sheep, well calculated to improve those of his kingdoms;—when we see the royal pursuits take such a direction, we may safely conclude, that the public measures which,

BLEACHING.





in certain instances, have been so hostile to the agriculture of this country, have nothing in common with the opinions of our gracious sovereign: such measures are the work of men, who never felt for husbandry; who never practised; who never loved it:—it is not such men that give rams to farmers.

Measure of the Royal Ram.

Girt, - - - -	42 inches
—— at chine, - - -	36
—— of neck, - - -	20
—— of leg, - - -	4½
Thickness, - - -	11
——— at chine, - -	9
Length of carcass, - -	23
——— of neck, - -	7
Breadth of loin, - - -	6
Weight, - - - -	91 lb.

The thickness, *hardness*, and closeness of his coat, are singular; the colour to the eye very dark, dirty, and even blackish, arising from the superior degree of closeness; but when opened, for examining the wool, the extreme beauty of the staple is at once apparent. The fibre fine; twisted; full of that yellowish waxy grease, that distinguishes the Spanish fleeces; the skin oily to an extraordinary degree.

In regard to the thriving quality of this breed, it is a point of such importance, that I was anxious to ascertain it: of the wool, none could have any doubt; but from certain points, which predominate in Spanish sheep, this was certainly a question; I had it not in my power to make a trial absolutely complete, but I formed a comparison, the result of which follows:—I tied him up in stalls during a part of the winter, and the rest of it he was in the field, fed exactly (during the whole) as other rams that were compared with him. In stalls, he beat the Norfolk breed.

No. 1.	Dec. 31,	Don Weighed - - -	84 lb.
2.		A ram ½ South Down, ¼ Norfolk, ¼ Bakewell, - -	141
3.		A South Down, from Mr. Ellman	136

These were fed abroad together till March 20th, when they weighed

No.	lb.	Gain.
1,	100	16
2,	148	7
3,	144	8

This was a superiority, which, I confess, I did not dream of.—The comparison is not exact, because the ages are not the same. No. 1, has eight broad teeth; No. 2, has six; and No. 3, has only four: but it seems to imply, that this ram is of a thriving race.

Another comparison of ram hoggets, proved favourable to the Spanish blood.

No.	Jan. 14.	Jan. 31.	Mar. 20.	G.
	lb.	lb.	lb.	
1, Half South Down, $\frac{1}{4}$ Bakewell, and $\frac{1}{4}$ Norfolk, -	97	94	82	0
2, Ditto, - - -	99	102	100	1
3, $\frac{1}{2}$ South Down, $\frac{1}{4}$ Spanish, $\frac{1}{4}$ Reyland, - - -	99	104	108	9
4, Ditto, a late lamb, - -	37	50	48	11
5, Seven whole bred South Down; average weight, -	80	81	94	14

It should seem, from this, and various other trials, that so small an addition as one-fourth of Norfolk blood does a marked and essential mischief. Of these, No. 4 much exceeds the rest, a sheep of 37 lb. gaining 11 lb. is in the proportion of 23 lb. gain by one of 80 lb. instead of which it is only 14 lb.

Speaking generally, I believe the Spanish blood will be found to have a good disposition to fatten, if not in the same class as some of our long woolled breeds, at least much superior to some of our fine woolled ones.

I put him to forty of my finest woolled South Down ewes, and therefore may expect to breed some rams well adapted to propagating fine wool, and some ewes, which, covered two years hence by Don, will give me a yet nearer approximation. A. Y.

[17 *Ann. Agr.* 529—533.

HYDROSTATIC ENGINE.

THIS invention, for which Messrs. Long and Hauto, have recently taken out letters patent, under the authority of the U. States, and which they have secured in England, Scotland and Ireland; is offered to the public, as a valuable and cheap substitute for the common overshot wheel, in all situations, where there is a scarcity of water, with a fall of 25 feet and upwards.

DON,

A Merino Ram given by his Majesty, to Arthur Young Esq. the Editor of the Annals of Agriculture, 1792.

This engine (say the Patentees) bids fair, with the improvements that ingenuity may suggest, to become one of the most powerful, and at the same time, one of the most simple water machines, that ever was invented.

References to the Plate.

Fig. 1. A perpendicular section of the box, &c. A a tube or canal, through which the water is coveyed into the engine. BB a box or cylinder, on which the pistons move. C a tube, that conducts the water from the box. DD the pistons, with their rods. E a valve, turning back and forth on a gudgeon, passing through its centre, and thus opening a communication alternately between the tube A, and each end of the box, and at the same time opening a communication between the box and the tube C, so that the water may be discharged from either end of the box, whilst the other is filling.

Fig. 2. A perpendicular section of the engine. ABBC, the same as in Fig. 1. DD a rack, the sides of which act alternately on the rack-wheel, thus producing a continued rotatory movement. Its change from side to side, is effected by means of cogs in the ends, which gearing into the cogs of the rack-wheel, alternately raise and lower it. E the rack-wheel. FF a fly-wheel turning on the shaft of the rack-wheel. GG a dog, moving on its axis *g*, at every change of the rack, and thus giving a reciprocated motion to the valve-rod. HH the valve-rod. I the winch acted upon, by the valve-rod, and giving motion to the valve, by means of its gudgeon. K a weight, suspended from the valve-rod, by a line passing over pullies, in the top of the dog. L one side of the groove-box to regulate the movements of the rack. M a lever connected with the dog by rods of iron. N one of the standards that support the lever. O a weight to balance the rack. P one side of the sweep.

Fig. 3. A horizontal section of the engine. AAA the frame of the engine. B the box with its pistons, &c. CCC a carriage connecting the pistons, and moving outside of the box. DD the sweeps connected to the carriage, by means of clevices, so that it may vibrate, in conformity to the movements of the rack, which is attached to it. E the rack as represented at D, Fig. 2. FF the sides of the groove-box. G the dog. HH the main shaft, upon which the fly and rack-wheels turn, and to which other machinery of any kind may be attached. II the fly-wheel.

Fig. 4. An internal view of one side of the groove-box, in which the sliders are so disposed, as to keep the sides of the rack alternately in gear, with the rack-wheel. The sliders represented by shades in this figure, are to consist of iron, and to be made fast to the sides of the groove-box, by means of screw-bolts. The uppermost is so constructed, as to permit the regulator in the end of the rack to pass around it.

Fig. 5. A view of a part of the dog, and its friction wheel, upon which the weight of the rack is supported.

Fig. 6. A view of one side of the frame at the back part of the machine, showing one of the grooves, in which that part of the carriage moves, to which the sweep is attached.

Fig. 7. A side view of the valve, with the winch by which it is turned.

Fig. 8. The pullies in the top of the dog, together with a part of the valve-rod.

Fig. 9. The carrier or regulator, to be attached to the lower part of the rack, at its outermost end. The ears upon the sides are fitted to the grooves of the groove-box, so that they pass entirely round the uppermost slider.

Figs. 10 and 11. The parts of the machine represented by these figures, are intended for a substitute for the groove-box and sliders. A model has been constructed on this plan, and it is found to answer the purpose far better, than the original plan. The greater part of the friction of the rack is completely done away by it. These figures represent different views of a catch-frame, with friction-wheels, bolts, and bolt-mortices. The friction wheels are placed so far asunder, as to admit the rack to pass freely between them. The frame at every change of the rack, rises and falls with it. It is confined in such a manner by the bolts, that it keeps the sides of the rack alternately in gear, with the rack-wheel. The bolts slip alternately into the mortices, by means of small weights, acting upon angular leavers or dogs; and are drawn out of them again, by the ends of the rack striking against pins or knobs, in the bolts.

According to Fig. 1, as the water acts alternately upon the pistons, it follows, that a reciprocated rectilinear motion is produced. This motion is accompanied by a power equal to the weight of a column of water, whose base is the area of one of the pistons, and whose height is equal to the whole perpendicular fall of the water. For instance let the whole perpendicular fall be 33 feet; the weight

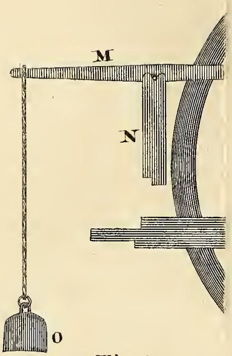
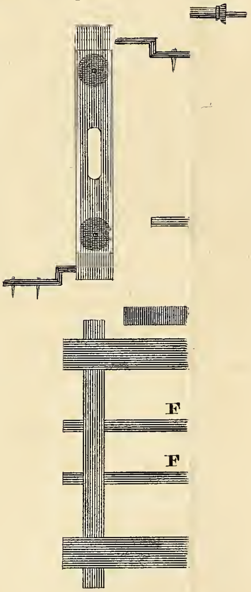
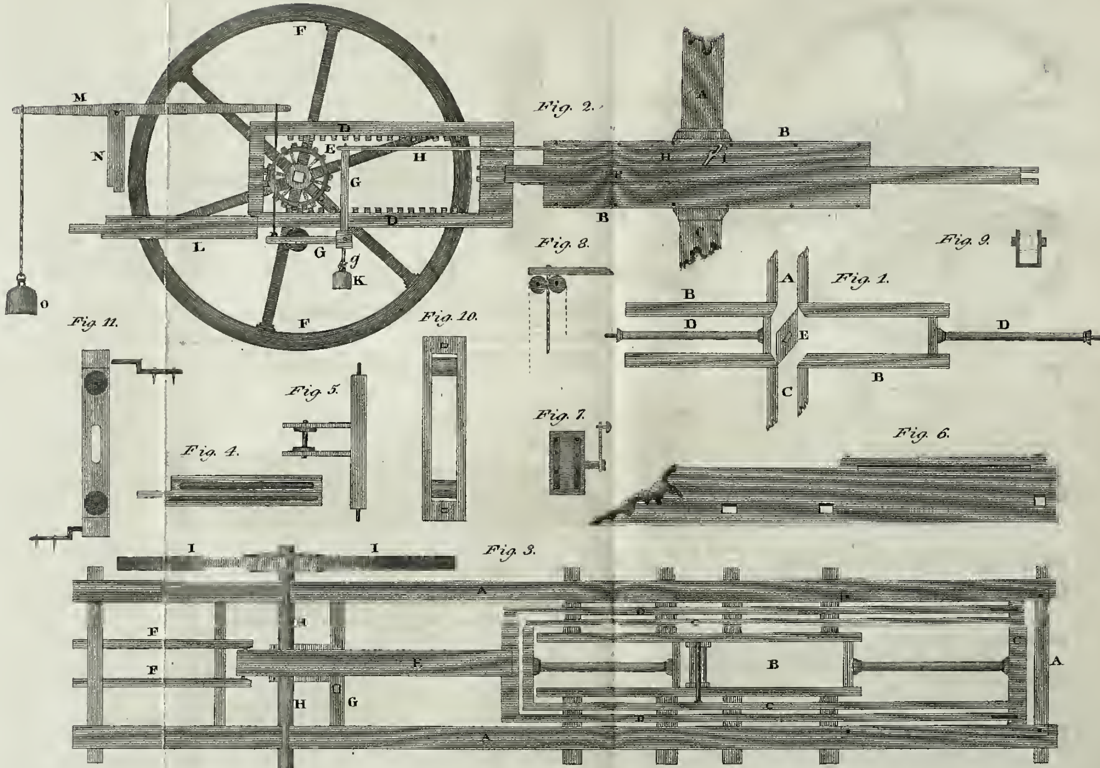


Fig. 11.



HYDROSTATIC ENGINE.



Engraved by H. Anderson, from an original drawing by W. Lehman.

or power will be 15 pounds upon every square inch of the piston. When the fall is sixty-six feet, the power is 30 pounds upon the square inch, and a fall of 132 feet will give a power of 60 pounds, upon every square inch of the piston, and so on. In order to apply the power thus acquired to machinery, it is necessary that a rotatory movement should be produced. The manner in which this is effected is shewn by Fig. 2; by which it appears that the rectilinear movement bears the same relation to the rotatory, that a line of tangent does to its circle; and this indeed is the only direction, in which a power acting in a right line, can produce a rotatory movement, without a very considerable loss.

It may be objected that the unavoidable friction to which the engine is liable, is sufficient to counterbalance all the advantages it might otherwise have, over the wheel, but an undeniable fact, which we will here introduce, will place this point beyond all controversy. An engine has been erected, at Mr. Bayly's brewery in Germantown, for the purpose of grinding malt. It is constructed on the original plan, viz. with sliders to regulate the movements of the rack. It is situated on a small stream of water, rising out of the ground, a few rods above the dam. The fall from the surface of the water in the dam, to the bottom of the machine, is equal to 25 feet perpendicular height. With this fall, grinding at the rate of 20 bushels per hour, the engine expends 100 gallons of water per minute. A grist-mill having an equal fall of water, and grinding at the rate of 3½ bushels of wheat per hour, requires about 400 gallons of water per minute, to turn it.

Farther information on the subject and licenses may be obtained, by applying to the patentees in Germantown, near Philadelphia.

Mr. Hauto's Hydrostatic Engine. I observe there has been a kind of newspaper controversy between the proprietors of this machine, and Mr. Perkins, in which the latter insists that the water is not so advantageously applied by Messrs. Long and Hauto, as if it fell on a common water wheel. I will not pretend to say but that the water power might so be managed with a water wheel perfectly constructed, as to do equal work, with the machine contrived by Messrs. Long and Hauto; but it seems to me, that their machinery could be placed in situations where a water wheel could not be employed—that in many cases it would be cheaper than a water wheel—and in all cases more efficacious where the stream of water from the top to the bottom of the fall was not preserved in uniform continuity, which in water wheels, is not, as I think, always

easy to be done. But I am not a good machinist, and have no pretensions to decide. Of this I am persuaded, that if a poor man in a cellar in Front street, could rent a stream from one of the hydrants sufficient to turn fifty spindles, or a single loom on Mr. Siddal's construction, he would enable one of his children to earn more wages than he could himself in any usual way of manual labour.

It is true, no fall is gained from the Schuylkill to the Delaware, but there are always machines that do actually raise the water for the purpose of renting it out in portions. And every inhabitant of Philadelphia, feels that such an establishment is a great public convenience. A man might afford to pay a high rent for the hundredth or five-hundredth part of the power of a twenty-horse engine, who could not afford to erect such an engine himself. I state this, merely as one of the cases that may be put, wherein small streams falling from a considerable height, might be advantageously employed; certainly not meaning or expecting that every or any house in Front or Water Street should be so occupied: I give it merely in illustration of the purposes to which the principle can be applied. No body, I presume, will deny that a small stream falling from a great height (that is with a great head) may far exceed in power a much larger stream that is shallow. Supposing the water could be, as it can be, conveyed from Schuylkill by steam engines, so as to supply a great number of small manufacturies conveniently situated with power enough to drive a few spindles or a loom or two, would not the erection of such engines ultimately pay a good rent to the proprietors, and greatly benefit small manufacturies, and the public of course? T. C.

MR. DUCKET'S PLOUGH. (PLATE.)

IN England, where agriculture is certainly better understood than in any other country in Europe; the land yields on the average of the Kingdom, 24 bushels of wheat per statute acre. This is managed by keeping it in heart either by

1st. Manure; every farmer in England making his dung and compost heap the first object of his attention.

2dly. By rotation of crops; in such a way that two grain crops never succeed each other; but are separated by a grass crop, or

else (not a fallow, but) a fallow crop: and high manuring for a potatoe crop precedes wheat.

3dly. By fallow-crops; fallows for the destruction of weeds being nearly given up all over the kingdom. A fallow crop, is one that will admit, and will require the ground in the intervals to be kept constantly free from weeds by hand hoeing, or hand weeding, like potatoes.

4thly. By making the grass land subservient to the arable. That is, so proportioning the meadow and the arable, that, the cattle fed on the former will supply dung enough to manure about one fourth of the whole farm every year.

But where, notwithstanding every precaution in collecting dung, and forming compost heaps, manure is scarce; as it always will be where the farm has too large a proportion of arable land, and the farm is understocked with sheep and cattle; then recourse is had to ploughing-in a green crop. This practice I have seen pursued now and then with much pleasure in Pennsylvania, where buckwheat is the crop usually ploughed down when just coming into flower. In England, the common plant used for this purpose is the tare or vetch vicia, sativa, aulgaris. But the common plough, either of England or this country, is inadequate to the performance of this very useful part of farming, with neatness and effect. I therefore present my readers with a plate of Mr. Ducket's skim-coultered plough, which gained the premium given by the Duke of Bedford, as well as the gold medal of the Board of Agriculture. It is taken from the 43d vol. of the Annals of Agriculture, for the year 1805. The editor of that work observes very justly that, "To think of attempting to plough-in any green crop by way of manure, or a long stubble, or the plentiful fragments left of a crop of tares, or weeds, or long dung, (with the common plough) is an idle expectation: no other plough will effect it. But this instrument executes the work in perfection. The skim is applicable to any plough." T. C.

POLITICAL ECONOMY.

Mr. Editor,

THE controversy about manufactures and commerce being rivals, seems to me very ridiculous. Every nation that has any claim to civilization must exercise agriculture, manufacturing and commerce: in proportion as the labour and capital of a nation are duly divided into these grand branches of human occupation, will the country be independent, the citizens happy, and serviceable to each other.

Except air, every thing necessary to the support of human existence, whether in the savage or civilized state, must be procured by labour: it is true a drink of water is come at with less trouble than a tumbler of wine; but still it requires exertions to get it. And pumps, wells, and aquaducts, are as important to society, as ships, clerks, and desks.

Without going into this controversy, which borders so closely on absurdity, let us temperately examine a few calculations that may throw some light on the subject of manufactures. Though Philadelphia, in many circumstances, does not resemble the cities of Europe, it will form a tolerable rule for the United States, it will therefore answer to exemplify, and to simplify the calculations. The population may be taken at 100,000, it is not much over or under this estimate, nor will an error here effect the general result.

1st. In a population of 100,000, it is probable there are 2,000 young boys and girls, not at school or engaged in any business; but from prejudice, pride, and other causes, many of their parents would not send them to work; let the number be reduced to 1000, and experience gives reason to suppose, they could at manufactures gain on an average $1 25 a week.

2d. There are also a number of young women who sew, bind hats, shoes, work for taylors, &c. but whose time, from want of employment, is not more than half occupied, and in consequence experience considerable distress; their number may be estimated at 500, and from the wages they now receive experience a loss, from this want of employment, of at least $1 50 a week.

3d. There is also a large body of labourers whose occupation is suspended three months in the year, their number is at least 400: the class exceeds this; but as they get occasional employ, those who are absolutely idle are estimated at 400, whose wages would be $5 a week.

4th. There is a number of elderly persons, whose strength is too much decayed for the toil of labourers or hired servants, and occupations where manufactories do NOT exist; who could be useful where they do; including both sexes, their number may be taken at 400, and wages estimated at $3 50 a week.

5th. Beside the preceding account of entirely lost time, there is a considerable portion of many families that would be employed in branches of manufactures that admit of being given out; such as tambouring, sewing up stockings, &c. &c. and supposing only one family in twenty took an interest in this, it would give 1000, whose industry would certainly produce $1 a week.

Now, without taking into account what would be gained by the capitalists who carried on the business—the merchants who sold the raw material and bought the manufactured goods—the increased demand for the produce of agriculture—the spring given to already existing trades—and the general effect on the country by such a creation of wealth, and keeping the circulation of money in the country; let us form an estimate of one year's gain of this 100,000 people, who are but a small proportion of the eight million now belonging to the United States.

First class, 1000 boys and girls at $1 25 a week would in the year produce	$ 65,000
2d Class, 500 young women, $1 50	39,000
3d Class, 500 labourers *out of* employ three months in the year, $5 a week	32,500
4th Class, 400 elderly persons, &c. $3 50	72,800
5th Class, 1000 families, at $1	52,000
	$ 261,300

To carry on this business, not less than seven or eight hundred thousand dollars would be required for the manufacturing capital; independent of the mercantile capital, direct and indirectly connected with it. J. R.

I am much obliged to my respectable friend and correspondent for this short but practical paper: it will come home to the understandings and feelings of many readers who, like himself, would regard my lucubrations and Dr. Bollman's, as useless and absurd. However, each of us in our way: we shall each of us do good to such of our readers, as may perchance be excited to *think* on these subjects. I would just observe, that although agriculture, manufactures, and commerce, are all necessary to a

civilized country, desirous of remaining civilized, yet it may prove a question neither useless or absurd to sit down and occasionally count the cost.

It has been proposed to raise silk worms, and manufacture indigo in England: and that nation was ready to go to war about Falkland's Island, and Nootka Sound, and Oczakoff: would the raising of mulberry trees and silk worms aid the agriculture, or the produce of indigo, keep the manufacture, or the commercial wars about these distant places, assist the commerce of that country? Is it a question of no importance, whether we shall protect a trade that brings us in a hundred thousand dollars, by a naval force that costs us half a million? Is it ridiculous to consider whether we shall support a manufacturing or commercial speculation, which would of itself be forever a losing concern to those embarked in it, if the rest of the nation were not taxed to afford them profit? May we not without much *waste* of time, expend an hour or two, in considering the relative value to the community, of capitals embarked in argriculture, manufactures and commerce respectively? I have readers of both opinions.

T. C.

NOTICES.

M. Berzelius is announced as having analyzed azot into 45 hydrogen, and 55 oxygen. We must wait for the details of the experiment, before we can give full credit to this important result.

I cannot insert Mr. Graafs communication in this number for want of room: nor Mr. Latrobe's, or Mr. J. Cutbushs's (which I much wished to include in the present number) for want of engravings for their figures; which I have now in train to be cut in wood. I want to add my own remarks to each of these papers. My trials met with the same result as Mr. Cutbushs'. They shall be inserted in the next Emporium.

Mr. J. Conrad is about publishing Davy's Chemical Elements of Agriculture: and Mr. Dobson goes on with Bancroft on permanent colours. I have perused both works; and they are well worth recommending to those who are interested in the pursuits they relate to. I rejoice to hear also of a new edition of Dr. Barton's Botany.

Mr. J. Cutbush has published the *Artists Manual*, 2 vols. 8vo. closely printed: (Johnson and Warner, and Fisher, South Fourth street.) This work contains the substance of Aikin's Chemical Dictionary, the Domestic Encyclopedia, and some similar publications. I do not know any book that includes so much scientific knowledge bearing upon manufactures, in the same compass, or at so small a price. I regard it as a compilation, made with judgment, and great industry, and a valuable addition to the useful literature of the country

I have not room in this number for an account of the loom that weaves by water power, or steam, invented, as I am informed by Mr. Siddal, at the calico printing works, about half a dozen miles on the New York road from Philadelphia. I shall gladly say more on this very important improvement. I have examined it with great satisfaction.

NEW DISCOVERY.

Thursday Evening, January 20, 1814.

Iode or Violaceous Gas. The Royal Society met after the holidays, when a paper from Sir H. Davy was read, describing a new and important discovery. About two years ago, a Parisian manufacturer of salt-petre, using all kinds of sea weed as a substitute for Barilla, discovered that his vessels were excessively corroded by a particular substance of a beautiful violet colour; he communicated the fact to some Paris chemists, but no particular notice was taken of it until Sir H. Davy went to Paris.

This new substance is easily procured by pouring sulphuric acid on the residuum of sea weed after the carbonat of soda has been extracted. It appears that all the vegetable products of the sea shore, yield it when thus treated. By pouring the acid on the residuary ashes of the sea weed, this new and most beautiful violet coloured gas is obtained.

The French propose calling it *iode* gas (from the Greek word *ion*, violet) but Sir H. D. prefers the term *violaceous* gas, as most suitable to English phraseology; its combination with hydrogene he agrees may be called *hydro-iodic gas*, &c. Its properties are equally important to the scientific chemist and manufacturer as a dye and pigment. It is the heaviest known gas; 100 cubic inches weighing 95-5. grains—it is easily disengaged at the temperature of 156; at a low one, it condenses into fine violet coloured chrystals; it is rapidly absorbed by the metals, uniting with iron, mercury, tin, lead, and zinc, and changing them into salts of the most beautiful tints of yellow, orange and brown. It has many analogies with oxygen, the alkalies, and chlorine or oxy-muriatic acid. Like the alkalies it has great affinity to oxygen, from which it can be expelled by heat; it experiences no change by the action of the voltaic pile, yet rapidly combines with phosphorus, hydrogen, and all the muriats; it is a non-conductor, is very slightly combustible, yet it is a supporter of combustion. It is so easily united with all the common metals, and converts them into such fine pigments, that before as many months elapse in this country, after its discovery, as years have done in Paris, it will be prepared by all our colour manufacturers, and used by our cabinet makers, wood stainers, and dyers. The existence of this substance tends to support an opinion of Sir H. D. that acids and alkalies do not depend on any peculiar acidifying principle, but on certain modifications of matter. All the iodats of iron zinc, are soluble in ether and spirits of wine, and many of them in water.

Alexander & Phillips, Printers, Carlisle.

THE

EMPORIUM

OF

ARTS AND SCIENCES.

VOL. III.] AUGUST, 1814. [No. II.

LEAD.

THE common ore, that which is almost exclusively worked, is the sulphuret of lead, or galena. This is usually a bluish ore in large plates or facets: when the facets are smaller, approaching to steel-grained, it is generally found to contain other metals, as silver, or antimony. It contains from 60 to 70 per cent. of lead.

It is most easily assayed in the dry way; most accurately in the moist way.

As silver in particular, and frequently also antimony is found combined with lead ore, it will be proper to give the assay and analysis of several kinds, which I shall do from Dr. Aikin, 1 Chem. Dict.

Assay and Analysis of the Ores.

The analysis of the ores of lead is upon the whole extremely simple. In general the moist way is the most accurate.

Before giving the individual processes the general methods may be mentioned whereby lead is separated from the other metals with which it is usually combined in the

different ores, and the data on which it may be estimated in analysis.

Lead is readily separated from silver by making a solution of both in nitric acid, and adding muriatic acid as long as any precipitate appears.

The silver falls down in the form of luna cornea, and with it a quantity of muriat of lead, and if the mixture stands some hours undisturbed, this latter salt also forms needled crystals on the surface of the luna cornea. All the silver falls down in this manner, but part only of the lead, and the muriat of lead is separated from the luna cornea by boiling water, 22 parts of which will dissolve 1 of muriat of lead, but not a particle of muriat of the silver. The solution of the muriat of lead is still more easily effected by digesting in dilute nitric acid, which dissolves it readily, but not the luna cornea.

Lead is separated from bismuth by dissolving both to saturation in nitric acid, either concentrated, or diluted with no more than a fourth of water, and then pouring the concentrated solution into a large quantity of water. The oxyd of bismuth then separates as a heavy white powder, and the lead remains dissolved. Some bismuth however remains, but to the solution may then be added a saturated solution of sulphat of soda, which will precipitate the lead only in the form of a white pulverulent sulphat of lead, the composition of which will be presently mentioned. But where all the bismuth is to be obtained for the purpose of analysis, and not merely to be separated from the lead, it is better after the bismuth has first precipitated, to add muriatic acid to the clear solution, which will throw down the silver, if there be any, and also some muriat of lead, mixed with some of the bismuth that remains in the solution, and which last if redissolved in nitric acid, will again be decomposed by water as before. The whole muriat of lead may then be dissolved in

water and nitric acid, and converted into a sulphat by means of sulphat of soda as before.

Lead is separated also from iron and copper by dissolving both in nitric or muriatic acid, and adding sulphat of soda to precipitate the lead. If the nitric acid be used, some of the oxyd of iron will first precipitate as a brown red ochre, which should be removed.

The same method will separate lead from tin, cobalt, and zinc.

The composition of the sulphat of lead artificially formed in these processes, has been given with some small variation by different chemists; Klaproth estimates it as follows.

100 parts of sulphat of lead, *dried at a low red heat*, are composed of 73.96 of oxyd of lead and 26.04 of sulphuric acid, and the above oxyd of lead is composed of 69.44 of metallic lead, and 4.52 of oxygen. This is not the only state of oxygenation of which lead is capable, but it is that in which, according to Klaproth, it is inferred to exist in all the native salts and oxyds of this metal hitherto analyzed.

It must be observed however, that this calculation gives a much lower state of oxygenation than is found by other experiments, as will be noticed presently, and the estimation of the quantity of metallic lead is made by other chemists, and even in other experiments of Professor Klaproth, to rise as high as about 71 per cent. Mr. Hatchett reckons it to be 70.9.

But where the muriat of lead is free from other admixture, the quantity of metal may be estimated without converting it into a sulphat, by the following data: 100 parts of lead dissolved in nitric acid, and decomposed by dropping in muriatic acid as long as any turbidness ensued, and evaporated to perfect dryness (but short of volatilization of any part of the combined muriatic acid) produced

133 of muriat of lead, and consequently 100 parts of dry muriat of lead indicate 75.2, nearly, of metallic lead, and (if oxygenated in the same degree as in the sulphat) 4.89 of oxygen, or 80.09 of oxyd of lead.

The muriat of lead may also be reduced by dissolving it in water and immersing a rod of iron, whereby the lead will be precipitated in the metallic state in fine lamellæ.

Some of the analyses of the individual lead ores may now be mentioned.

Vauquelin analyzed a galena from Cologne in the following way.

A quantity was roasted slowly and lost 12 per cent. of sulphur in the process. Another quantity was heated with very dilute nitric acid, which gave a smell of sulphuretted hydrogen, and dissolved all the metallic part. The undissolved residue heated to redness, parted with its sulphur, and 16.67 per cent. of silex was left. The nitric solution was then decomposed by sulphat of soda, and the sulphat of lead collected and weighed. The proportion of metal it contained (estimating 100 of the sulphat to be equivalent to 75.72 of metal) was 63.1 per cent. The liquor was then saturated with ammonia, which deposited 3.3 of oxyd of iron, and lastly carbonat of potash threw down 5 of carbonat of lime.

In the *dry way* the galena after roasting may be mixed with thrice its weight of black flux,* covered with salt, and melted, when a button of reduced lead will be found

* Black flux is made by deflagrating together in a red hot crucible equal weights of crude argol or tartar, and nitre. In a common way, roast an ounce of the powdered ore for two hours frequently stirring it: then add to it, of pounded green glass an equal weight, and of borax and black flux each also an equal weight, with 10 grains of lamp-black. If thrice the weight of black flux be used, the alkali will dissolve some of the lead.

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at the bottom, which will also contain the silver and other metals if present.

The triple sulphuret of lead, antimony, and copper found in Cornwall, was thus analyzed by Mr. Hatchett.

Two hundred grains were put into a matrass with two ounces of muriatic acid, and heated, and nitric acid was added drop by drop, till the whole moderately effervesced. It was then gently heated for an hour, and a green solution was formed, on which floated a quantity of sulphur, which was collected, digested separately with a little muriatic acid, and then washed and dried. It weighed 34 grains, and afterwards burned away in a red hot earthen cup, without residue, and therefore was pure. The solution, with the muriatic acid in which the sulphur had been washed, was boiled, and then mixed with 6 pints of boiling distilled water, which it rendered instantly milky, and was filtered while hot, and the filter washed with more boiling water. The white precipitate left on the filter, when dried on a sand bath, weighed 63 grains, and was oxyd of antimony. The liquor with the washings deposited on cooling some crystallized muriat of lead. It was evaporated nearly to dryness, and a few drops of sulphuric acid added to the liquor left, to separate in the form of a sulphat, what little of the lead remained in solution. The residue was then redissolved in boiling water, and decomposed entirely by sulphat of soda, and the sulphat of lead thus produced, (added to the former portion) was washed and dried on a sand bath, and weighed 120.2 grains.

The liquor which was now bluish-green, was rendered of a deep blue by ammonia, and a small quantity of oxyd of iron separated, which when dried and heated with wax, became magnetic, and weighed 2.4 grains.

The liquor was then evaporated nearly to dryness, boiled with a strong lixivium of potash till nearly dry, and on

washing with water, some black oxyd of copper was left weighing 32 grains after thorough drying.

In the above analysis the metals are estimated as in their metallic state, this being the state in which they exist in the sulphurets, and hence, for the 63 grains of oxyd of antimony, 48.46 of the regulus are to be put down, and for the 120.2 of sulphat of lead, the author estimates 85.24 of metallic lead, which is in the proportion of 70.9 in 100.

The carbonat of lead was analyzed by Klaproth in the following way: 100 grains were dissolved in a mixture of 200 grains of nitric acid with 300 of water, and the loss of weight by the effervescence noted, which amounted to 16 grains, and was carbonic acid. The nitric solution was then diluted, and a cylinder of zinc immersed, which precipitated the lead in the metallic state in beautiful vegetations. This washed and dried, weighed 77 grains, equivalent to 82 of oxyd, as it is in this state that the lead exists in the ore. This proportion however, would give an increase of only 6.5 of oxygen upon 100 of lead.

That rare variety of lead ore, the compound carbonat and muriat of lead, has been analyzed both by Klaproth and Chenevix. By Klaproth, the following method was pursued: fifty grains of the ore were rubbed with 150 of very pure carbonat of potash, (previously freed from every muriat) and heated in a platina crucible to a moderate redness, then lixiviated and filtered. An oxyd of lead was left behind. The solution was slightly supersaturated with nitric acid and precipitated with nitrat of silver. The muriat of silver thus obtained weighed 27 grains, equal to more than 4 of concrete muriatic acid. Another quantity of the ore of 100 grains was then powdered and nitric acid affused, which produced an effervescence of carbonic acid. This solution gave with nitrated silver 55 grains of luna cornea, corresponding very closely in proportion with the former experiment, the acid of

which amounted to 8.5 grains. The lead was then precipitated by *caustic* potash and the oxyd thus procured weighed, after thorough drying, 85 1-2 grains, which is the state of oxygenation in which it is supposed to exist in the ore. In this case, therefore, 85.5 grains of oxyd of lead were combined with only 8.5 of muriatic acid which is far short of the saturating quantity, since in the artificial crystallized muriat of lead the proportion of acid amounts to 13 or 14 per cent. This deficient saturation therefore allows the presence of carbonic acid, which amounts to 6 grains, and completes the saturation of oxyd.

A similar ore was analyzed by Mr. Chenevix, nearly in the same way and with the same result. The ore was first dissolved in nitric acid, and the quantity of carbonic acid, amounting to 6 grains, estimated by the loss after effervescence. The solution was then neutralized by ammonia, and tried by different tests. As nitrate of lime gave no precipitate, the solution could not contain either the arsenic or molybdic or phosphoric acids, and as nitrat of barytes gave none, the absence of sulphuric acid was proved.

Nitrat of silver was then added and a copious precipitate ensued, and the luna cornea weighed after drying 48 grains, which Mr. C. estimates as equivalent to 8 of muriatic acid. The composition of the ore is thus stated: 6 grains of carbonic acid saturate 34 of oxyd of lead, and 8 of muriatic acid saturate 51 of oxyd of lead, and the acids may be supposed to be in the state of perfect saturation, consequently the ore is composed of 59 muriat of lead and 40 of carbonat of lead; or of 14 of acid and 85 of oxyd.

The Anglesea sulphat of lead was thus analyzed by Klaproth: 100 grains were first ignited moderately and lost two grains, which were water of crystallization. The remainder was mixed with 400 grains of carbonated pot-

ash, and kept for some time in a red heat in a platina crucible, which gave a reddish-yellow hardened mass. This, digested with water, was all dissolved except the oxyd of lead separated in the previous process, amounting to 72 grains, after strong drying. This oxyd was redissolved in nitric acid, and deposited thereby one grain of oxyd of iron. The solution was then decomposed by zinc, and yielded 66.5 grains of metallic lead. The alkaline fluid formed by the washing of the contents of the crucible, after ignition, was then saturated with nitric acid and acetate of barytes added as long as any sulphat of barytes was precipitated. This amounted to 73 grains, equal to 24.8 of concrete sulphuric acid on the estimation that 100 parts (after ignition) contain 34 of acid. The iron in this ore appears merely casual.

The phosphated lead ores have been also examined by the same eminent Chemist with much attention. The composition of all the varieties is very uniform, all consisting of phosphoric acid and oxyd of lead, together with muriatic acid, the quantity of which varies very little. It is a distinguishing and singular property of the phosphat of lead, that when melted into a round bubble under the blow-pipe it assumes a regular polygonal garnet-shaped form on the moment of solidifying by cooling.

The green phosphat was thus analyzed: after some imperfect attempts at reduction in the dry way, 100 grains of the ore were dissolved in hot nitric acid leaving no residue. Nitrat of silver then gave a precipitate of 11 grains of luna cornea, the muriatic acid of which amounted to 1.7 grains. Sulphuric acid was then added to the warmed solution, by which sulphat of lead was precipitated, weighing after ignition 106 grains, equal to 73.61 of metallic lead or 78.4 of the oxyd. The liquor was then freed from the excess of sulphuric acid by nitrat of barytes, it was then nearly saturated with ammonia, and ace-

tite of lead added. The phosphoric acid in the solution, was then precipitated in the form of phosphat of lead, weighing, after ignition, 82 grains, of which the mere acid amounts to 18.37 grains. The rest of the solution was then mixed with a little muriatic acid, inspissiated by evaporation, and alcohol added to redissolve the muriat of iron then formed, if any, from which by the addition of prussiat of potash there was obtained an extremely small blue precipitate, indicating no more than about .1 of a grain of oxyd of iron.

In another experiment the phosphoric acid, instead of being engaged with lead, was saturated partly by soda, partly by ammonia, and by due evaporation and cooling, crystals of the microcosmic salt, or the phosphat of soda and ammonia were obtained. The other varieties of this phosphat were analyzed in the same way.

With regard to the analysis of the molybdat of lead the reader is referred to the article *Molybdena* and to *Chrome*, for the Chromat of lead. Those ores in which lead is only a small part of the metallic contents will be described under the other metals as silver, bismuth, &c.

The compound of oxyd of arsenic, lead, and iron, examined by Lelievre, and Vauquelin, gave the following appearances: 100 parts roasted for half an hour, with a little suet added occasionally to favour the evaporation of the arsenic, lost 38, and became black and magnetical. The remaining 62 parts boiled in muriatic acid made a red solution, giving out much oxymuriatic acid gas, and crystallized muriat of lead was deposited. This solution evaporated, redissolved in water, and decomposed by sulphat of soda, gave 25 of sulphat of lead, equal to 20.2 of lead or 22 of the oxyd. The residue, saturated with ammonia, gave 39 parts of oxyd of iron.

The analysis of lead ores in the dry way is attended

with much more loss of the metallic contents, especially when alkaline fluxes are used, all of which act more or less on this oxyd.

Smelting and reduction of Lead Ores.

The only ore of lead that is wrought in the large way is galena, and the method of treating this is very simple, partly on account of the richness of the ore, and partly on account of the low price of the metal itself, which therefore will not admit of any but the most summary methods of bringing it into a marketable state.

The ore when first brought up from the mine is *dressed* by women and boys, who with a hand-hammer separate the greater part of the adhering impurities, consisting of blende, iron, pyrites, quartz, calcareous spar, &c. The residue being broken into pieces about the size of a hazle-nut, is washed from all adhering clay and dirt, and is then ready to be smelted. The furnace used for this purpose is the common reverberatory with a low arch. A ton or more of the ore is spread on the floor of the furnace, and by means of the flame from pit-coal it is quickly brought to a bright red heat. In this situation it is occasionally stirred with iron rakes to expose fresh surfaces to the action of the flame and facilitate the separation of the sulphur. In a short time the mass begins to acquire a pasty consistence; upon which the heat is lowered and the ore is kept at a dull red till the sulphur is nearly all got rid of; the fire being then increased the ore is brought to a state of perfect fusion, and visibly consists of two fluids; the lower is the metallic lead, the upper is a vitreous slag, still holding a considerable portion of lead but mixed with various impurities. In this state of the process the fire is damped and a few spadefuls of quicklime are thrown into the fluid mass; by this, the scoriæ are suddenly solidified, and are raked to the side of the furnace; the tap-hole is

then opened, and the lead runs into moulds placed to receive it, where it congeals into oblong masses called *pigs*, weighing about 60 pounds each. As soon as the lead has run out of the furnace, the tap-hole is closed, the scoriæ are replaced in the bed, and being quickly raised to a glowing red heat are soon melted; the greatest part of the lead that they contained by this means collects into a mass at the bottom; a little lime is thrown in as before, the scoriæ thus rendered solid are raked aside, and the lead which they covered is let off into a mould. This second scoriæ, though still holding from 5 to 8 per cent. of lead, is now removed from the furnace, and applied to no purpose but that of mending roads, the expence of separating the last portions of metal being more than the value of the produce.

The lead of the first running is the best; that procured from the scoriæ being sensibly harder, and less malleable on account of the iron that it contains.

It is a matter of doubt among the most intelligent smelters whether there is any advantage in retaining the carbonat of lead, with which the galena is very often mixed in considerable proportion. On the one hand it is certain that it contains a large quantity of metal, and in assays is very easily reducible; but on the other hand, when treated in the reverberatory, it vitrifies almost at the first impression of the heat, and being a very active flux it is apt to bring the whole into fusion while much sulphur still remains unsublimed; hence the amount of scoriæ is prodigiously increased, and with it the trouble of the smelters, while the produce of lead is very little augmented. [2 *Aikin*, 14.

The following practical remarks of the Bishop of Landaff, are well worth attention.

It is not fifty years since the *blast* or *hearth* furnace, was the only one in use for smelting lead ore in *Derby-*

shire. In this furnace, ore and charcoal, or ore and what they call white coal, which is wood dried but not charred, being placed in alternate layers, upon a hearth properly constructed, the fire is raised by the blast of a bellows, moved by a water wheel; the ore is soon smelted by the violence of the fire, and the lead as it is produced trickles down a proper channel, into a place contrived for its reception. There are not at present, I believe, above one or two of these *ore hearths* in the whole county of Derby; this kind of furnace, however, is not likely to go entirely out of use, since it is frequently applied to the extracting lead from the *slag* which is produced either at the *ore hearth*, or the *cupola* furnace, and it is then called a *slag hearth*; and the lead thus obtained is called *slag lead*: the fire in a slag hearth is made of the cinder of pitcoal instead of charcoal of wood.

The furnace called a *cupol* or *cupola*, in which ores are smelted by the flame of pitcoal, is said to have been invented about the year 1798, by a physician named *Wright*, though Beccher may, perhaps, be thought to have a prior claim to its invention or introduction from Germany. But whoever was the first inventor of the cupola, it is now in general use, not only in Derbyshire and other counties, for the smelting of ores of lead, but both at home and abroad, where it is called the English furnace, for the smelting of copper ores. This furnace is so contrived, that the ore is melted, not by coming into immediate contact with the fuel, but by the reverberation of the flame upon it. The bottom of the furnace on which the lead ore is placed, is somewhat concave, shelving from the sides towards the middle; its roof is low and arched, resembling the roof of a baker's oven; the fire is placed at one end of the furnace, upon an iron grate, to the bottom of which the air has free access; at the other end opposite to the fire-place, is a high perpendicular chimney; the

direction of the flame, when all the apertures in the sides of the furnace are closed up, is necessarily determined, by the stream of air which enters at the grate, towards the chimney, and in tending thither it strikes upon the roof of the furnace, and being reverberated from thence upon the ore, it soon melts it.

It is not always an easy matter to meet with a current of water sufficient to move the bellows required in smelting on an hearth furnace; and to carry the ore from the mine where it is dug to a considerable distance to be smelted, is attended with great expence; this expence is saved by smelting in the cupola furnace, which not requiring the use of bellows, may be constructed any where. Wood is very scarce in every mining county in England; and though pitcoal costs ten or twelve shillings a ton in Derbyshire, (1787) yet they can smelt a definite quantity of ore in the cupola, at a far less expence by means of pitcoal, than of wood.—The flame which plays upon the surface of the ore and smelts it in a cupola furnace, is not driven against it with much violence; by this means small particles of ore, called *belland*, may be smelted in a cupola furnace with great convenience, which would be driven away, if exposed to the fierce blast of a pair of bellows in a hearth furnace. These are some of the advantages attending the use of a cupola in preference to a hearth furnace; and to these may be added one superior to all the rest,—the preservation of the workmen's lives; the noxious particles of lead are carried up the chimney in a cupola, whilst they are driven in the face of the hearth smelter at every blast of the bellows.*

They generally put into the cupola furnace a ton of ore, previously beat small and properly dressed, at one time;

* In the neighbourhood also of blast furnaces, the chimney is lined, and the adjacent ground covered with the white oxyd of lead which is lost to the smelter. T. C.

this quantity they call a *charge*; if the ore is very poor in lead, they put in somewhat more, and they work off three charges of ore in every twenty-four hours. In about six hours from the time of charging, the ore becomes as fluid as milk. Before the ore becomes fluid, and even whilst it continues in a state of fusion, a considerable portion of its weight is carried off through the chimney; what remains in the furnace consists of two different substances,—of the lead, for the obtaining of which the process was commenced,—and of the *slag* or *scoriæ*. The proportion between these parts is not always the same, even in the same kind of ore; it depending much upon the management of the fire. The lead, being heavier than the slag, sinks through it as it is formed, and settles into the concavity of the bottom of the furnace. The pure slag, according to the idea here given, is that part of the ore of lead which is neither driven off by the heat of the furnace, nor changed into lead. In order to obtain the lead free from the slag which swims over it, the smelters usually throw in about a bushel of lime; not, as is usually supposed, in order to contribute towards the more perfect fusion of the ore, but to dry up the slag which floats upon the surface of the lead, and which, being as liquid as lead, might otherwise flow out along with it. The slag being thus thickened by an admixture of lime, is raked up towards the sides of the furnace, and the lead is left at the bottom. There is a hole in one of the sides of the furnace, which is properly stopped during the smelting of the ore; when the slag is raked off, this hole is opened, and being situated lower than the lead in the furnace, the lead gushes through it into an iron pot placed contiguous to the side of the furnace; from this pot it is laded into iron moulds, each containing what they call a pig of lead; the pigs, when cold, being ordinarily stamped with the maker's name, are sold under the name of

ore lead. After the lead has all flowed out of the furnace, they stop up the tap-hole, and drawing down the slag and lime into the middle of the furnace, they raise the fire till the mixture of slag and lime, which they simply term slag, is rendered very liquid; upon this liquid mass, they throw another quantity of lime to dry it up, as in the former part of the process. This second mixture of slag and lime is then raked out of the furnace, and the small portion of lead separated from the fusion of the first, generally to the amount of twenty or thirty pounds, being let out of the furnace, a new charge of ore is put in, and the operation re-commenced. In order to spare the lime, and the expence of fuel attending the fluxing of the mixture of lime and slag, they have in some furnaces lately contrived a hole, through which they suffer the main part of the liquid slag to flow out, before they tap the furnace for the lead; upon the little remaining slag they throw a small portion of lime, and draw the mixture out of the furnace without smelting it. This kind of furnace they have nick-named a *Maccaroni.*

The process of smelting here described, appears to be defective in some points, which I will take the liberty to mention, and at the same time suggest the means of improvement; without, however, presuming to say, how far it may be expedient to adopt the proposed alterations; being sensible that what may appear very feasible in theory, or may even answer in small assays, may not be practicable in large works.

The first alteration which I would propose to the consideration of the lead smelters, is to substitute an horizontal chimney of two or three hundred yards in length, in the place of the perpendicular one now in use. In the preceding Essay, which was first published in 1778, mention is made of the probability of saving a large quantity of sublimed lead, by making the smoke which rises from

the ore pass through a horizontal chimney, with various windings to condense the vapour. I have since conversed with some of the principal lead smelters in *Derbyshire*, and find that I had over-rated the quantity of this sublimed lead; the weight of the *scoriæ* from a ton of ore, amounting to more than I had supposed; they were all of them, however, of opinion, that the plan I had proposed for saving the sublimate, was a very rational one. But so difficult is it to wean artists from their ancient ways of operating, that I question very much whether any of them would ever have adopted the plan they approved, if an horizontal chimney, which was built a little time ago in *Middleton dale*, for a quite different purpose, had not given them a full proof of the practicability of saving the sublimate of lead, which was lost in the ordinary method of smelting. This chimney was built on the side of an hill to prevent some adjoining pastures from being injured by the smoke of the furnace. It not only answers that end, but it is found also to collect considerable quantities of the lead, which is sublimed during the smelting of the ore; this sublimed lead is of a whitish cast, and is sold to the painters at ten or twelve pounds a ton; it might perhaps be converted into red lead with still more profit.

A second circumstance to be attended to in the smelting of lead ore, is the saving the sulphur contained in it. The pure lead ore of Derbyshire contains between an eighth and a ninth part of its weight of sulphur; but as the ore which is smelted is never pure, being mixed with particles of *spar*, *cawk*, *limestone*, *brazil*, and other substances, which the miners call *deads* we shall be high enough in our supposition, if we say that the ordinary ore contains a tenth of its weight of sulphur; it may not, probably, contain so much, but even a twelfth part, could it be collected at a small expence, would be an object of great impartance to the smelter. In the common method

of smelting lead ore there is no appearance of the sulphur it contains, it is consumed by the flame of the furnace, as soon as it is separated from the ore; an attentive observer may, indeed, by looking into the furnace, distinguish a diversity in the colour of the flame, at different periods of the process; during the first three or four hours after the ore is put into the furnace, the flame has a bluish tint, proceeding no doubt from the sulphur which, in being sublimed from the ore, is inflamed: after all the sulphur is separated from the ore, the flame has a whitish cast, and then, and not before, the fire may be raised for finishing the operation; for if the fire be made strong before the sulphur be dispersed, the quantity of lead is less, probably, for two reasons; the sulphur unites itself in part to the lead which is formed, and by this union becomes inseparable from it; for the sulphur cannot without much difficulty be separated from an artificial mixture of lead and sulphur, when the two ingredients have been fused together.—2. The sulphur, whilst it continues united to the lead in the natural ore, renders the ore volatile, so that in a strong heat a great portion of it is driven off. Hence, very sulphureous ores should be roasted for a long time with a gentle heat, and in this proper management of the fire, principally consists the superiority of one smelter above another.

An old lead smelter informed me that he had often reduced a ton of ore to sixteen hundred weight by roasting it, but that he did not obtain more metal from it by a subsequent fusion, than if he had fluxed it without a previous roasting. This may be true of some sorts of ore, but it is not true of very sulphureous ores. Indeed the fire may be so regulated in a cupola furnace, as to make it answer the purpose of a roasting and a smelting furnace at the same time. I have seen much lead lost by smelting a ton of sulphureous ore in eight hours, which might

have been saved, if the fire had at first been kept so gentle as to have allowed twelve hours for finishing the operation.

Sulphur cannot be separated from lead ore in close vessels, and the lead ore melts with so small a degree of heat, that there may be more difficulty in procuring the sulphur from the ores of lead, than from those of copper or iron, however, I am far from thinking the matter impracticable, though I have not yet hit upon the method of doing it; and the following reflections may, perhaps, tend to supercede the necessity of collecting the sulphur in substance.

When it is said that the sulphur is consumed by the flame of the furnace as soon as it is separated from the ore, the reader will please to recollect, that sulphur consists of two parts,—of an inflammable part, by which it is rendered combustible,—and of an acid part, which is set at liberty, in the form of vapour, during the burning of the sulphur. Now this acid, though it may be driven out of the furnace in the form of a vapour, yet it is incapable of being thereby decomposed; it still continues to be an acid; and, could the vapour be condensed, might answer all the same purposes as the acid of vitriol; since all the acid of vitriol, now used in commerce, is actually procured from the burning of sulphur. That the fact, with respect to the acid not being decomposed, is as I have stated it, may be readily proved. The smoke which issues out of the chimney for some hours after each fresh charge of ore, has a suffocating smell, perfectly resembling the smell of burning brimstone; and if a wet cloth, or a wet hand, be held in it for a very short space of time, and afterwards applied to the tongue, a strong acid will be sensibly perceived. Various methods may be invented for condensing this acid vapour, and, probably, more commodious than the following one, which, however, I will just take

the liberty of mentioning, as, if it should not succeed, the trial will be attended with very little expence.

Supposing then an horizontal chimney to be built, let the end farthest from the fire be turned up by a tube of earthen ware, or otherwise, so that the sulphureous acid may issue out in a direction parallel to the flue of the chimney, and at the distance of about a foot and an half above it. Let a number of large globular vessels be made of either glass or lead, each of these globes must have two necks so as to be capable of being inserted into one another; let these vessels be placed on the flue of the chimney, the neck of the first being inserted into the tube through which we have supposed the sulphureous acid to issue, and the neck of the last being left open, for fear of injuring the draught of the furnace. Let each of these globular vessels contain a small quantity of water, then it is conceived, that the heat of the flue will raise the water into vapour, and that this watery vapour will be the means of condensing the sulphureous acid vapour, if not wholly, at least in such a degree as may render the undertaking profitable.* When the sulphur is all consumed, the draught of the furnace may be suffered to have its ordinary exit at the end of the horizontal chimney, by a very slight contrivance of a moveable damper. Since the first publication of the preceding Essay, I have seen an horizontal chimney at the copper works near Liverpool, where every thing I had said concerning the probability of saving sulphur by roasting lead ore, is verified with respect to copper ore; and I believe a patent has been granted to some individual for this mode of collecting sulphur. Sulphur might be obtained with equal facility from the *pyrites* which is found amongst coal, and

* The sulphur *may* be worth saving, but I greatly doubt if the vitriolic acid be. T. C.

this application of the pyrites might, probably, be more lucrative than the present one—making green vitriol.

A third circumstance, which requires the utmost care of the lead smelter, is the leaving as little lead as possible in the slag. Near every smelting-house there are thousands of tons of slag, which when properly assayed, are found to yield from one-eighth to one-tenth of their weight of lead; though no person has yet discovered a method of extracting so much from them when smelted in large quantities; and indeed the smelters are so little able to obtain all the lead contained in them, that in many places they never attempt to extract any part of it: in some places where they do attempt it, I have known the proprietor of the slag allow the smelters 20s. for every pig of lead they procured of the value of 38s. besides furnishing them with fuel: and yet the men employed in such an unwholesome business, seldom made above 7s. a week of their labour. This fusion of the slag of a cupola furnace is made, as has been mentioned, at a hearth furnace; the coal cinder, which they use as fuel, and the slag, are soon melted by the strong blast of the bellows into a black mass, which, when the fire is very strong, becomes a perfect glass; this black mass, even in its most liquid state, is very tenacious, and hinders many of the particles of lead from subsiding, and it being from time to time removed from the furnace, a considerable quantity of lead is left in it, and thereby lost. A principal part of the lead contained in the slag of the cupola furnace, is not, I apprehend, in the form of a metal, but in the form of a litharge or calcined lead: a portion of the lead, in being smelted from its ore, is calcined by the violence of the fire; this calcined lead is not only very vitrifiable of itself, but it helps to vitrify the spar which is mixed with the ore, and thus constitutes the liquid scoriæ; might it not be useful to throw a quantity of charcoal dust upon the liquid scoriæ

in the cupola furnace, in order that the calcined lead might be converted into lead, by uniting itself to the inflammable principle of the charcoal?*—Iron will not unite with lead, but it readily unites with sulphur, and, when added to a mixture of lead and sulphur, it will absorb the sulphur, leaving the lead in its metallic form; might it not be useful to flux sulphureous lead ores in conjunction with the scales or other refuse pieces of iron, or even with some sorts of iron ore?—The smelter's great care should be to extract as much lead as possible at the first operation of smelting the ore, and to leave the slag as poor as possible; but if he should still find either the slag of the cupola furnace, or that of the hearth furnace, containing much lead (as that even of the hearth furnace certainly does), he may, perhaps, find it worth his while to reduce the slag into a powder by a stamping mill, or by laying it in highways to be ground by the carts, or by some other contrivance, and then he may separate the stony part of the slag from the metallic, by washing the whole in water, inasmuch as the metallic part is far heavier than the other.

I estimated the weights of several pieces of slag, and found them to differ very much from each other; this difference is principally to be attributed to the different quantities of lead left in them.

Weight of a cubic foot of

	Avoir. oz.
Slag from a cupola furnace where no lime was used - - -	3742
Black slag from a hearth furnace -	3652
Another piece - - - - -	3612
Black slag from another hearth furnace—struck fire with steel -	3378
Black glass slag - - - -	3371.

[3 *Watson's Chem. Essays*, 272—298.

* This is on the Stahlian or phlogistic theory. T. C.

The following article on the smelting of lead from Dr. Rees's Cyclopædia contains also many remarks of practical consequence.

Reduction of the Ores, or smelting of Lead.

Two processes are employed for the smelting of lead, the one by means of a blast furnace, called an ore-hearth, and the other by means of a reverberatory furnace. The latter is used throughout Derbyshire and North Wales, and is undoubtedly the best, where coal is not very scarce. In the former of these methods the ore and the fuel are mixed together, and exposed to the blast. The heat dissipates the sulphuret,* the ore being the common sulphuret of lead or galena. A portion of the lead is oxydated, which facilitates the vitrification of the earthy parts of the ore, and of the fuel. These together constitute the slag or scoriæ. The metallic lead falls into the lower part of the hearth, and is defended from the oxygen of the blast by the scoriæ, which is fluid upon its surface. The liquid lead is let off from time to time, always retaining a portion for the scoriæ to float upon. When the whole of the lead is to be drawn off, the blast must be stopped, and some lime thrown upon the liquid scoriæ, which renders it concrete, while the lead, being still liquid, can be run off.

The reverberatory furnace employed for smelting lead is made on the same plan with those commonly used for puddling iron, differing in size, and a few other particulars. The fire is made at one end, and the flame plays over the hearth, entering an oblique chimney at the end, which terminates in a perpendicular one, of considerable height. The length of the hearth, from the place where the fire enters, to the chimney, is 11 feet; two feet of this length next the fire constitutes the throat of the furnace; the width of the same is four feet, and its depth

* Rather the sulphur.—T. C.

about six inches; the length of the fire-place is four feet, equal to the width of the throat; its width two feet, and depth three feet, from the grate up to the throat of the furnace. The rest of the hearth is a concave surface nine feet long, four and a half feet wide at the throat of the furnace, seven feet four inches wide at the distance of two feet from the throat, seven feet two inches in the middle of the hearth, five feet eleven inches at two feet distance from the chimney, and two feet ten where the flame enters the chimney at two apertures, each ten inches square. These apertures terminate in the oblique part of the chimney, the section of which is 16 inches square, which communicates with the main chimney, the section of which is twenty inches square, supposing a straight horizontal line, drawn from the lower plane of the throat of the chimney to the opposite side of the furnace; the lowest part of the concave hearth, which is in the middle of this cavity, is nineteen inches below this line, the roof of the furnace being seventeen inches above the same line: the rest of the hearth is conformably concave.

On each side of the furnace are three openings, each about ten inches square, provided with iron doors, to be removed as occasion may require. They are arranged at equal distances from each other, between the commencement of the hollow hearth and the entrance into the chimney. The lower part of these apertures is on a level with the horizontal line above alluded to, being for the purpose of stirring and raking the ore, &c. Besides the larger openings there are two small apertures, one below the large middle opening, and nearly on a level with the bottom of the furnace; the other under that next to the chimney, at some distance above the first aperture. The first is a tap-hole for the lead, and the second for the scoriæ. The ore is introduced by a vessel in the shape of a hopper, placed in the roof of the furnace.

Previous to the ore being smelted, it requires to be separated as much as possible from the earthy matter in which it is imbedded. Although galena, which is the ore used for smelting, is most frequently accompanied by sulphat of barytes, fluats and carbonat of lime, it is found to exist in crystallized distinct masses, and can be separated from it by mechanical means to a tolerable extent. The whole of the ore, with the earthy matter, is pounded to a certain degree with hammers; this is chiefly performed by women. In some places, however, it is broken down by passing it through iron rollers pressed together by great weights. After the ore has been thus reduced, the earthy matter is separated by washing. The powder to be washed is introduced into a sieve or riddle, and placed in a large tub full of water. By a certain motion given to the riddle, the lighter or earthy parts are thrown over the edge of the same, while the galena, by its greater specific gravity, is retained. This process requires great dexterity, which can be acquired by experience only. There are, however, some impurities which cannot be separated by this mechanical process, and are generally smelted with the ore. These are *blind** or *black-jack*, called by the smelter *mock* ore, pyrites, or sulphuret of iron, named *brazil* by the workmen. When the ore abounds much with these substances, the process of smelting is more difficult, and requires an extra assistance of flux to reduce it.

In the state above described, the ore is introduced at the hopper in the middle of the roof of the furnace, and spread upon the concave hearth, to expose it as much to the flame as possible, in order to facilitate the escape of the sulphur. This should be performed by a long continued heat which *is not violent*, in order that the sulphuret itself may not be volatilized, an effect which, more or less, always takes place. The moment the sulphur has left the lead, it be-

* Blende. Sulphuret of zinc.—T. C.

gins to combine with oxygen. The oxyd of lead, thus formed, combines with the earthy matter, which it renders so fusible as to become liquid upon the sulphur of the melted lead, and defends it from the future action of the oxygen. At this stage of the process the fire is raised to separate as quickly as possible the melted lead from the liquid scoriæ. The latter is now let off at the upper tap-hole, leaving a small portion still upon the lead to preserve it from the air. The fire at this period is lowered, and a quantity of coal-slack thrown in upon the melted mass. This serves as well to facilitate the cooling, and to cause the reduction of some oxyd of lead, which also tends to stiffen the melted scoriæ. This last effect, however, is not produced sufficiently, till a quantity of powdered lime is thrown into the furnace. By this treatment the remaining scoriæ becomes concrete, and is then broken to pieces and pushed to the opposite side by means of a rake, and taken out of the furnace at the different openings on the same side. The liquid lead is now let out, at its proper aperture, into a large iron pan, or cistern, from whence it is laded into moulds to cast into pigs. The furnace is now ready to be charged again. When the ore abounds with much impurity, the oxyd of lead is not sufficient to give the proper degree of liquidity to the scoriæ. In this case a certain quantity of fluat of lime is added, which has the property of forming a very fusible compound with sulphat of barytes, an ingredient very common in the ore.

This flux has been used from time immemorial for the same purpose, and has no doubt derived its name from its properties as a flux.

The concrete scoriæ, which is taken out of the furnace, is found to contain some lead, independent of that in the state of oxyd, and chemically combined. This is generally lodged in the cavities of the spongy mass. These

masses are taken to a kind of blast furnace, called a slag-hearth. By this second fusion of the scoriæ, the lead drops through the liquid mass into the lower part of the hearth, where it is not acted upon by the blast, and from thence is let off and cast into pigs. This lead is said to be of an inferior quality. Some ores of lead contain silver. The great affinity of lead for that metal is such, that the whole of it is found in the lead, from whence it is afterwards separated. [*Brewster's Cyclopædia.*

On the Smelting of Lead.

Dear Sir—Most of the lead of commerce is obtained from that species of ore which is by mineralogists called *galena*, *potter's ore*, or sulphuret of lead. Indeed, it is the only species of lead ore which is found in sufficient quantities to be worth working.

There are many other species of lead ore met with occasionally; but these, occurring but seldom, are regarded as curiosities, and are generally carefully selected for the cabinet of the mineralogist, or as ornaments for the mantlepiece of the miner.

The ore, as it is first raised from the mine, is mixed with a considerable proportion of the matrix or gangue of the vein, from which it must be in great measure freed before it is fit for the operation of smelting.

For this purpose, the ore is delivered to the *dressers*, who either break it into small pieces with hand-hammers of a peculiar construction, which are called *buckers*, or it is passed between rollers worked by machinery, or under stampers. It then undergoes the operation of washing, to separate it from the lighter foreign matter, after which it is ready for the smelter.

Construction of the Ore Hearth.

The smelting of lead is performed differently in different districts. In most parts of the North, particularly in

Smelting of Lead.

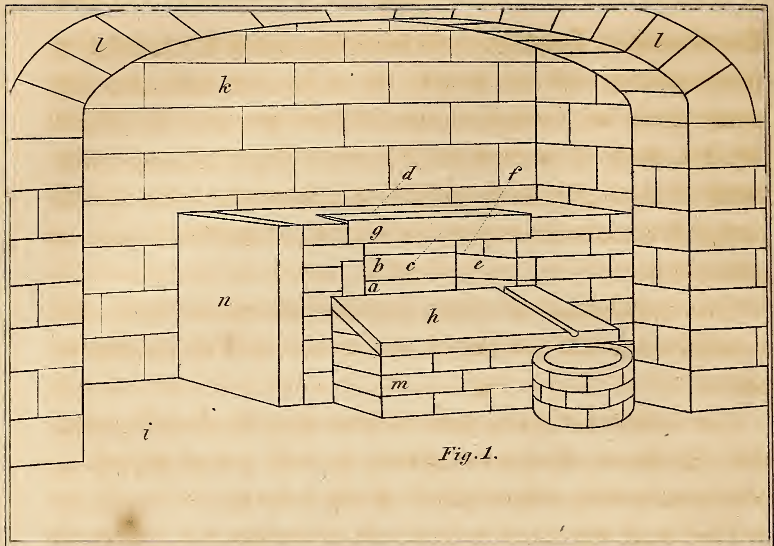


Fig. 1.

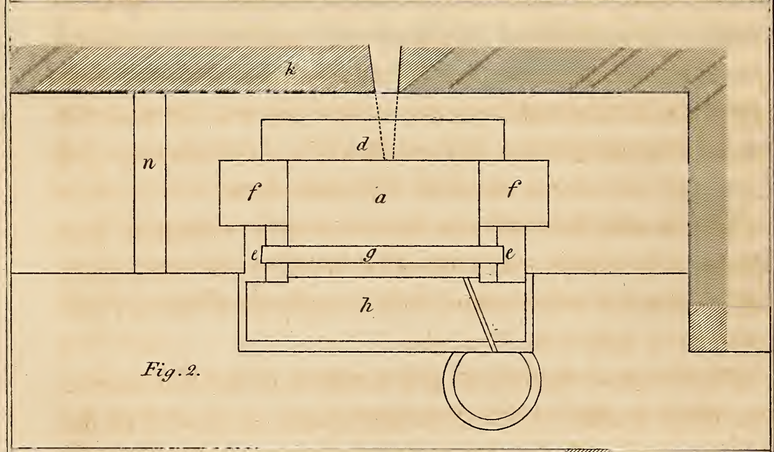


Fig. 2.

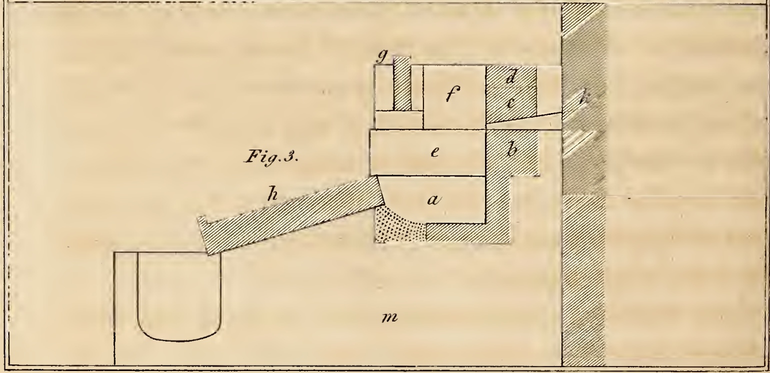


Fig. 3.

H. Anderson sc.

Cumberland, Durham, and Northumberland, smelting is performed in the ore hearth by means of bellows. In some parts of Yorkshire, in Derbyshire, and in North Wales, lead is smelted in reverberating furnaces: this kind of smelting is distinguished from the other by the name of cupola smelting: each of these methods has its advocates.

The superiority of either depends much on local circumstances, and, perhaps, also on the skill of the workmen.

Ore-hearth smelting shall be first described.—To render the description intelligible, it will be necessary to commence with a description of the hearth.

Fig. 1, of the plate, is a sketch of the hearth: it is constructed principally of pieces of cast iron, which are called generally iron stones or metal stones; each different casting has a distinguishing name: they are the (*a*) pan, (*b*) back, (*c*) pipe-stone, (*d*) spark-stone, (*e*) bearers, (*f*) keys, (*g*) fore-stone, and the (*h*) work-stone.

The hearth is erected under a spacious chimney, and nearly in the centre; one side of it is called the water-side, being near the water-wheel, which urges the bellows; the opposite is called the land-side.

Figs. 2 and 3 are plans and sections of the ore-hearth: the same letters in the different figures are placed to the same parts.—(*i*) the floor of the smelting-house, (*k*) the back of the chimney, (*l*) the front of the chimney, (*m*) the foundation on which the hearth is constructed: it is built of rough masonry, and levelled and run in at the top with thin mortar or grout; the pan or bottom of the hearth is laid steadily in mortar on this bed: upon the posterior part of the pan is placed the back, its face being even with the inner edge of the pan.

The work-stone is next arranged; its upper edge three or four inches from the anterior part of the pan, and pa-

rallel with the back; the bearers are placed on the sides of the pan, one end of each butting against the back, the other ends resting on the upper edge of the work-stone. Two thin pieces of stone, (about half an inch thick,) generally slaty sandstone, are laid on the back, and on these is placed the pipe-stone, the inner face of which overhangs the back near an inch. The keys are set on the bearers, their faces even with them; two pieces of brick are set on edge on the bearers, next to the keys, and on these, a few inches from the keys, rests the fore-stone; the spark-stone laid on the pipe-stone completes the hearth.

Before laying the foundation, a large flat stone (*n*) called the cheek-stone is fixed firmly in the ground, and determines the extent of the land-side of the hearth; the spaces between the water-side, the back of the chimney, and the cheek-stone are filled up with pieces of sandstone, bricks, or old iron-stones, and the interstices levelled up with dust. The fore-stone is wedged tight by its ends, generally against two old keys.

The space between the pan and the work-stone is filled with a mixture of bone and fern ashes well beaten in, and those between the keys and the ends of the fore-stone with stiff clay.

Care is taken in constructing the hearth to lay the bearers square, or at right angles with the back, and also to direct the blast immediately through the centre.

The hearth being completed, the operation of smelting commences with kindling the fire. The whole space between the fore-stone and back is filled with peats or chop-wood: an ignited peat or live coal being placed in the midst, the bellows are set to work: as soon as the combustion is sufficiently advanced, or that the whole are well on fire, one of the smelters (there are two to each hearth) throws a few shovels of half-smelted ore, (the remains of the last operation of smelting,) which is termed brouse,

on the top of the fire, gradually adding more as the contents of the hearth settle; he also adds a few small coals occasionally to keep up the combustion; when the whole of the brouse is thrown on the hearth, the other smelter watches-out; that is, with a long pointed crow-bar, called a gavel or gable-hook, he stirs up the whole of the brouse, and brings forward a great part of it upon the work-stone: this is effected by introducing the gable-hook into the hearth six different times, in the following order: he first forces it under the brouse a few inches on one side the centre, until the point touches the back; he then forces as low down as he can the end he holds in his hand; this lightens up the contents of the hearth, and as the bar is withdrawn, a part of the hot brouse comes forward on the work-stone; the gable-hook is then entered below the brouse, about the same distance from the centre, on the other side, where the same operation is performed: it is next introduced close to the side of the hearth; here the workman forces the end of the gable-hook from him, at the same time he presses it down, so as to bring the point of the bar into the middle of the hearth; this brings part of the brouse, which was next the side, into the middle, and what was in front, out on the work-stone. The gable-hook is again introduced in the same place, and the point raised close to the side, to remove any brouse that may adhere to the bearer or key. The same operation is performed at the other side, to remove the brouse from thence also. Whilst the watcher is performing his part, the man who supplied the hearth, and who is called the setter-on, thrusts his shovel down into the hearth, a little below the entrance of the blast, and forces the brouse sufficiently forward to allow him to place a peat or a handful of chop-wood horizontally before the orifice of the bellows: this he generally gets done nearly as soon as the other has finished watching, who changes his gable-hook for a sho-

vel; the setter-on comes to the front with his shovel, and they together throw the whole of the brouse again into the hearth, over the fore-stone, with a small quantity of coal as they see necessary, carefully separating the slags, which they throw into a corner, and breaking down the larger masses of brouse: when the whole is in the hearth, the setter-on goes again to the side, levels the top of the brouse, and covers it with fresh ore, laying this thickest against the spark-stone: the working of the hearth, after watching, is called setting-up. When a hearth is well set-up, and works properly, without an excess of coals or blast, and pretty free from slags, small reddish white flames issue from all parts of the breast, from below the fore-stone, nearly to the edge of the work-stone: these flames should not issue more than a few inches from the breast. The hearth does not continue long in this state; as the peat burns away, the blast is less equally distributed; it forces itself through more in some parts than in others; the covering at the top is perforated, or, perhaps, perfectly ignited, and the whole mass is condensed and settled in consequence of the evaporation of one part of the ore, and the separation of the metal; copious blueish flames issue from two or three parts of the hearth, as if occasioned by the combustion of some metal. The brouse must be again watched-out, a new peat put in, and more ore thrown on the top. The operations of watching and setting-up require to be repeated about every three minutes. After a few times setting-up, the metallic lead begins to flow down the channel of the work-stone, into a pot, where it is kept hot until collected in sufficient quantity to cast a pig.

It is necessary, for the easy management of the hearth, that a considerable quantity of fluid lead should remain in the bottom for the brouse to float on. The watcher, after throwing up the brouse, allows the lead to flow freely

down the gutter for a short time, and then prevents any more escaping, by lightly raising up the brouse against the gutter with the corner of his shovel.

Two men will smelt about six bings of good ore a day, and from these produce 24 pigs of lead, weighing 154lbs. each.

It is advisable to draw the hearth at the end of every twelve hours, in order that it may cool; for a cool hearth works pleasanter, and makes better produce than one which has been suffered to heat. The hearth should be drawn about two watchings after throwing on the last of the six bings of ore. As soon as the hearth is watched-out the last time, the action of the bellows is stopped, and the smelters draw out the whole of the hot brouse with their shovels, and throw it on the floor to cool, picking out such slags as they may observe; they also remove whatever adheres to the sides or back.

If the hearth has been properly attended, and a due proportion of fuel used, it will scarcely appear hotter in one part than another; and, if it has been working with a free ore, should not appear hotter than a very dull obscure red heat.

With a free ore, the hearth, when fresh set-up, works as before described, the blast finding its way equally through all parts of the breast. The brouse, when watched-out, is dry, and mostly in small pieces, the slags firm, and easily distinguished by their cavernous appearance and brighter colour, and the lead flows from the hearth scarcely red hot. Lead ore, which contains much silver or copper, or which has not been properly cleared from the gangue with which it is mixed in the vein, requires particular attention on the part of the smelter: instead of working dry and open, it becomes soft and pasty; the slag, instead of separating in firm pieces, is diffused through the whole like a half-melted scoria, and the least

inattention to the fire will set the whole contents of the hearth into a solid mass, or cause it to boil and flow down in a liquid state on the work-stone—the lead flows very hot, and the hearth appears hot and foul. The addition of lime is necessary to correct this defect in the ore, which combining with the fluid scoriæ, solidifies, and thus assists its collecting in masses: care should be taken not to add more lime than is absolutely necessary for the purpose intended, as all extraneous matter thrown in with the ore lessens the produce of lead.

The substances which are found to render the ores of lead refractory, when mixed with them, are cawk, (*sulphate of barytes*,) black jack, (*blende* or *sulphuret of zinc*,) sulphur, (*iron pyrites*,) and silver, or copper, when they are contained in the ore in larger proportions than usual.

I have always considered that these substances render an ore refractory by the extra quantity of sulphur they bring with them. I do not think the earth or metals alone would produce any visible effect in the smelting; and I am almost confirmed in this opinion, by repeatedly observing the effect produced by roasting the ore previous to smelting; it works more pleasantly, requires less lime and fuel, and gives a better produce.

The quality of the coals materially affects the working of the hearth and the produce of lead; those which are free from sulphur, and which leave but little residuum after combustion, are the best fitted for smelting.

The lead which is separated directly from the ore, is called ore lead, or common lead, to distinguish it from that which is the result of a subsequent process.

Slag-hearth Smelting.

The slags or scoriæ separated in the process of ore-hearth smelting, consist of the infusible part of the ore, the ashes of the coals, peats, &c. semi-vitrified and aggluti-

nated by a quantity of oxyd of lead produced by the action of the blast; they contain also particles of metallic lead dispersed through their substance, and not unfrequently unreduced ore.

These scoria, which are technically named *gray slags*, vary considerably in the quantity of lead they contain, but the poorest hold a sufficient quantity to pay the expense of smelting.

As it is necessary to bring these slags to a perfect fusion to separate the lead, a furnace capable of producing a more intense heat than the ore-hearth is requisite. The plate contains plans, sections, &c. of the slag hearth, in which the same letters are applied to the same parts in the different figures. Fig. 1 is a perspective view of the hearth; Fig. 2 a plan; and Fig. 3 a perpendicular section; (*a*) a cast-iron plate, which forms the bottom of the hearth: an old work-stone is generally used for this purpose; what it wants in dimensions is supplied by other old castings, refuse of the ore-hearth: the bottom is laid in fine dust which has been damped a little, and well rammed; on the bottom is placed the back (*b*) which is formed of three or four old bearers laid on each other; on the centre of the back is placed the tuyre, or as it is generally called the *tue-iron*. The pipe-stone (*c*) is bedded in tempered clay on the back; it is a block of freestone about 15 or 18 inches square, and 30 long, hollowed out on the underside to fit the tuyre. Two old bearers (*d d*) about 18 inches apart, and placed at right angles with the back, against which their ends butt, form the lower part of the sides; on these, two blocks of freestone (*e e*), about 15 by 18, and in length equal to the height of the pipe-stone, are placed on end; the front is built entirely with old castings, the lower one resting on the ends of the side bearers.

The spaces between the back of the chimney, the side and the cheek stone, are filled with old castings, bricks, or pieces of stone, and the joints filled up with dust or ashes; the space left between the bottom of the hearth and the lower front bearer is called the breast;—*(f)* is the sump or pot to contain the lead, as it flows from the hearth; the space between the breast and the sump is paved with old castings imbedded in dust, and the joints filled with thin mortar grout; near the sump is a mould for casting the lead into pigs.

The hearth is prepared for working, by slightly ramming into the bottom a quantity of coal ashes; the sump is also filled, and the space between it and the breast; the dotted part *(g g g)* fig. 3, represents the coal ashes: the fire is next lighted, and when the interior of the hearth has acquired a good red heat, the smelter throws on a few shovels full of gray slags (which have been previously broken to the size of an egg), and as the hearth settles, occasionally adds fuel or more slags as may be required: in a few minutes after charging with the slags a small perforation is made in the breast by passing a pointed iron rod through the ashes close to the bearer; the liquid scoriæ and lead flow through this opening down the inclined plane formed by the ashes; as they become hot the lead filters through them, and finds its way into the sump; the scoriæ from its viscidity remaining on the surface, from whence it is removed occasionally as it cools and becomes hard.

The slag hearth is continued working for 12 or 14 hours, the smelter adding materials occasionally as required, and judging of the proportion of fuel by the heat and appearance of the fluid scoria.

At the conclusion of the day's work the hearth is suffered to burn down as low as possible; and when the scoria ceases to flow, the bellows are stopped, the scoria on the

bed of ashes removed, and the lead which has collected in the sump is cast into pigs. Cool ashes are next spread over the hot bed, and the hearth drawn and cleared from what remains in it, and when moderately cooled, prepared with a bottom of ashes for a succeeding day's work.

The principal art in working a slag hearth is to keep a proper *noze*, and to have the hearth light and open in front, otherwise the blast does not work well and diffuse itself equally through all parts, but forces itself up behind and very soon destroys the pipe-stone.

The noze is a protuberance which surrounds the orifice, through which the blast passes; it is formed by the vitrified slags trickling down the pipe-stone, and cooled by the blast as it enters the hearth. With very fusible slags it is sometimes difficult to get a proper noze to form, and with refractory slags to keep it of a moderate size. With too large a protuberance, the hearth works most at front; with too small, chiefly at the back.

In general a noze may be prevented growing too large, by laying the fuel principally near the pipe-stone, and occasionally forcing in a pricker through the tuyre.

A noze may be enlarged by a contrary situation of the fuel, and throwing in close to the pipe-stone a few shovels of dust and ashes from the top of the hearth.

The fuel used at the slag hearth is coke.

The scoria, the refuse of the operation in the slag hearth, is called black slag; it contains a portion of metallic lead which is separated by stamping and washing.

The lead obtained by the slag hearth is hard and sonorous; it is of an inferior quality, and unfit for many of the purposes to which common lead is applied.

Cupola Smelting.

For the method of smelting lead by the cupola furnace as principally practised in Derbyshire, I refer to Watson's Chemical Essays; a more correct or interesting account cannot be given, (already inserted).—38 *Phil. Mag.* 371.

The process for refining Lead, as practised in England. In a letter from Mr. John Sadler.

WITH TWO ENGRAVINGS.*

MY dear Sir—Citizen Duhamel, in his Memoir on the refining of Lead in the large way, has given a sketch of the process used in England; if you think the following more detailed description will be acceptable to the readers of the Philosophical Journal, it is at your service.

The object of refining lead is not merely on account of the silver it contains, but to procure it as free as possible from the other metals with which it is usually alloyed, and to procure litharge. The silver is only an object, so far as it helps to pay the expense of refining.

The lead produced at the smelting hearths or furnaces in England is never perfectly pure; it is always alloyed with a portion of silver, and most commonly with one or most of the following metals; namely, zinc, antimony, copper, and arsenic; which render it unfit for some of the purposes to which lead is applied.

The operation of refining is founded on the facility with which lead is oxydated when exposed to heat in contact with atmospheric air, and the peculiar properties the oxyds of lead possess; being easily fused, and in that state oxydating and combining with most of the metals; gold, silver, and platina excepted.

* These will be given in the next number.

Refining Furnace.

Fig 1.

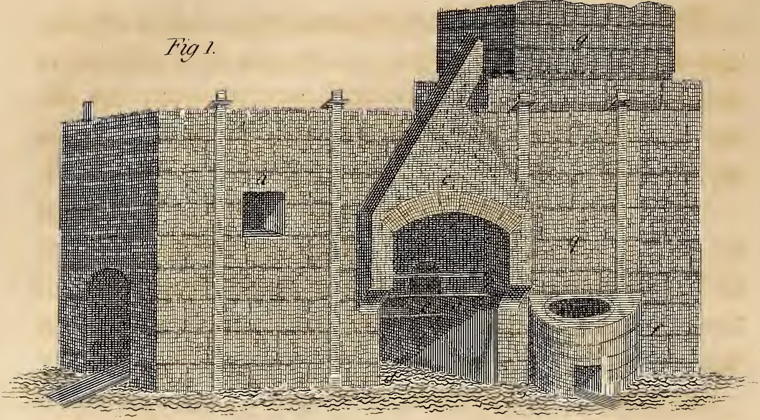


Fig 2.

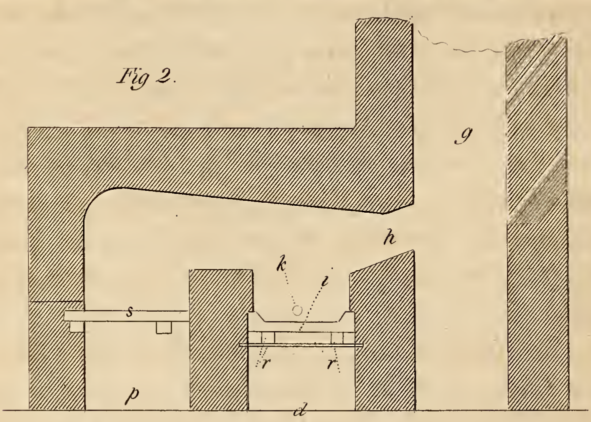
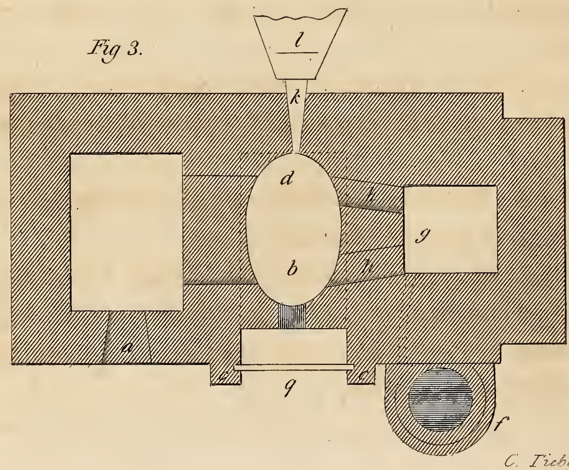


Fig 3.



C. Tiebout.

The lead to be refined is exposed to the action of heat and air upon a *cupel* or *test*, composed of a mixture of bone and fern ashes, in a reverberatory furnace; the description of which, with the different manipulations, are as follows:

The refining furnace is composed of good solid masonry, bound together with iron bolts. It differs very little in its construction from the common reverberatory furnace, except the bottom, which is perforated to receive the test or cupel.

Fig. 1, plate I, of the refining furnace is a perspective view of the furnace with its iron work; *a* the teazing hole, *b* aperture by which the test is supplied with lead, *c* an arch or dome over the feeding hole, communicating with the furnace stack by a flue, *d* area or space where the test is taken in and out the furnace, *ee* two strong iron bars to support the test when in its place, *f* cast iron pot set in masonry, the flue passing into the stack of the furnace, *g* the stack, *p* the ash pit, *q* an iron bar to slide the ladle on when feeding the test.

Fig. 2, a perpendicular section of the furnace showing the test *i*, supported in its place under the opening of the bottom of the furnace by the two wedges *rr*; *k* aperture for the nozzle of the bellows, *s* fire bar resting on the bearers.

Fig. 3, plan of the interior of the furnace; *l* part of the bellows, *hh* flues from the body of the furnace to the stack.

The same letters in the different plans are meant to denote the same parts, in the next plate.

Plate II, fig. 1, plan of the iron frame into which the mixture of bone and fern ashes is rammed to form the test. This frame is something larger than the elliptical hole in the bottom of the furnace.

Figs. 2 and 3, plan and section of the test; *m* the part which contains the lead to be refined, *n* breast of the test, *oo* small gutters or channels through which the litharge flows, *p* a semi-elliptical hole for the litharge to fall through from the gutters, upon the area of the refinery.

These drawings and references will be sufficient to make the description of the furnace, &c. clearly understood.

Of the Test or Cupel.

A good test is of the first importance in refining; the method of constructing one I shall endeavour to point out. Six parts of well burnt bone ashes and one part of good fern ashes are to be well mixed, sifted through a sieve, (the spaces in which are about one-eighth of an inch square,) and moistened to about the same degree the founders use their sand. The iron frame is to be laid on the floor and made steady, with wedges under its rim; about two inches in thickness of the ashes are to be equally spread over the bottom, and with an iron beater, such as used by the founders, equally rammed between the cross bars; the frame is to be again filled and rammed all over, beginning at the circumference and working spiral ways until finished in the centre, the filling and ramming to be repeated until the frame is completely full; an excavation to contain the lead is made as expressed in the plan, with a sharpe spade about five inches square, the edges dressed with a long bladed knife; a semi-elliptical hole, as at *p*, is to be cut through the breast. Having proceeded so far, the test is to be turned on its side and dressed from all superfluous ashes adhering to the bottom, taking care that none shall be left flush with the bottom of the frame or cross bars, otherwise in fixing the test to its situation at the bottom of the furnace it would be liable to be bulged.

Refining of Lead.

Fig. 1.

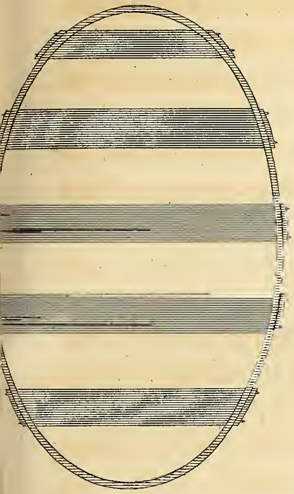


Fig. 2.

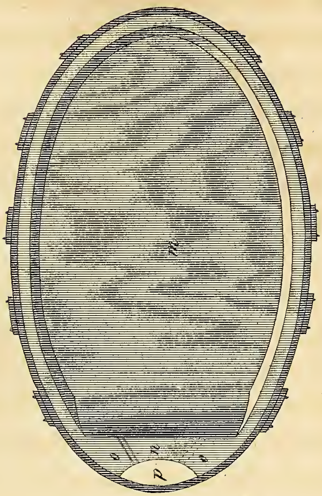
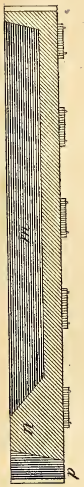
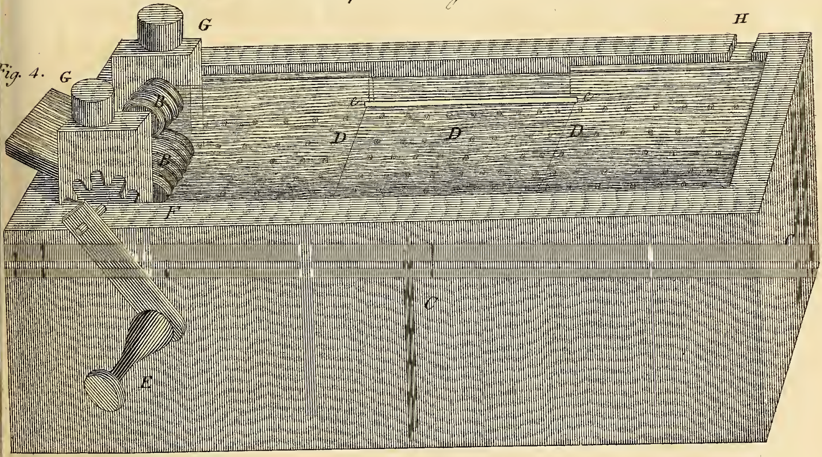


Fig. 3.



Ward's Machine for working in White Lead.

ig. 4.



H. Anderson sc.

Fixing the Test in its situation.

The rim of the test is now to be plastered with clay or moistened ashes, placed upon the supporting cross bars, and fixed with wedges firmly against the bottom of the furnace, the breast next to the feeding hole.

A gentle fire may now be lighted, and gradually increased until the test be red hot. When it ceases to emit steam from the under side it is sufficiently dry.

Lead previously melted in the iron pot *f* is ladled into the test until the hollow part be nearly filled, the operator closes the feeding aperture, and increases the heat of the furnace until the surface of the lead is well covered with litharge; he then removes the door from the feeding hole, and with an iron rod, which has one end bent down at right angles about three inches, and made flat or chissel-shaped, scrapes the small gutter or channel *o* until the litharge just flows into it, the blast from a pair of double bellows is then directed from the back part over the surface of the test, the litharge is urged forward, and flows from the gutter upon the floor of the refinery; the operation now goes forward, gradually adding lead as the escape of litharge makes necessary, until the gutter is so worn down that the test does not contain more than an inch in depth of lead, the blast is then taken off, the gutter filled up with moistened ashes, and a fresh one made on the other side the brest; the test is again filled, though not so full as at first, and the operation carried on until this gutter also is worn down and the test contain from about fifty to seventy pounds of alloy. This quantity is run into an iron pot, and set by until a sufficient number of pieces have been collected to make it worth while to take off a plate of pure silver from them.

The quantity of alloy left in the working off each test must depend in a great measure upon the quantity of silver it by estimation is supposed to contain. A sufficient

quantity of lead should always be left in the alloy to make it fuse easily in the iron pot.

When the test is removed from the furnace and broken up, the litharge will be found to have penetrated to an inconsiderable but equal depth in the ashes; that part not impregnated with litharge may be pulverised, mixed with fresh ashes, and again used for another test.

The operation of taking off the silver pure, differs in no respect from the foregoing, only more care is observed in the working, not to suffer the escape of any metallic particles with the litharge, as that would occasion considerable waste of silver. As the process advances, and the proportion of silver to lead increases, the litharge assumes a darker colour, a greater heat becomes necessary, and at last the brightening takes place; the interior of the furnace, which during the whole of the process had been very obscure and misty, clears up. When the operator observes the surface of the silver to be free from litharge, he removes the blast of the bellows, and suffers the furnace to cool gradually; as the silver cools many protuberances arise on the surface, and fluid silver is ejected from them with considerable force, which falling again on the plate spots it very fantastically with small globules.

The latter portions of litharge bring over a considerable quantity of silver with them; this is generally reduced by itself and again refined.

The litharge as it falls upon the floor of the refinery is occasionally removed; it is in clots at first, but after a short time as it cools it falls for the most part like slacked lime, and appears in the brilliant scales it is met with in commerce: if it is intended as an article for sale, nothing more is necessary than to sift it from the clots which have not fallen and pack it in barrels.

If, on the contrary, it is intended to be manufactured into pure lead, it is placed in a reverberatory furnace,

mixed with clean small-coal, and exposed to a heat just sufficient to fuse the litharge. The metal as it is reduced flows through an aperture into an iron pot, and is cast into pigs for sale. During the reducing, care is taken to keep the whole surface of the litharge in the furnace covered with small-coal.

In some smelt works, instead of a reverberatory furnace for reducing, a blast furnace is made use of, on account of the greater produce, but the lead so reduced is never so pure as that made in the wind furnace. The oxyds of the metals, which require a greater heat to reduce than the lead, are in the blast furnace generally reduced with it.

The volatile oxyds, as zinc, antimony, and arsenic, are mostly carried off by evaporation during refining; a considerable portion of the oxyd of lead itself is carried off by evaporation, making the interior of the furnace so misty and obscure, that a person unused to refining cannot see more than a few inches into it.

A considerable portion of these oxyds are driven by the blast of the bellows through the feeding aperture, and would be dissipated in the refining-house, to the great injury of the workmen's healths; to prevent their ill effects the arch or dome over the feeding hole is erected to carry the fume into the stack of the furnace.

15 *Nicholson*, 1.

PROPERTIES of the metal LEAD. Lead obtained free from any other metallic mixture, (as by precipitating nitrat or acetat of lead by zinc) is when recently melted of a bright bluish-white colour, which soon tarnishes on exposure to air: but when once tarnished, lasts a long time exposed to the weather, for it does not decompose water as iron and copper do. It is the softest of the com-

mon metals. Its specific gravity is 11,35, which is not encreased by hammering. It is very malleable, but not very ductile. A wire of $\frac{1}{12,6}$ of an inch diameter supports only 18,4 lbs. its point of fusion is 612°. It evaporates in the common blast-heat of the hearth furnace. It combines with oxygen slowly, by means of heat. The oxyds appear to me to be, 1st, The greyish black dust that first appears on the surface of the melted lead. 2dly, The yellow massicot, which also is first of a dirty yellow and then of a greenish yellow, before it comes to be of a full yellow colour; indicating, as I conjecture, various states of oxydation. This yellow oxyd is massicot, to which red lead also may be reduced, by driving off a portion of its oxygen; though it is usually made, in the stage of the process that precedes the red lead. It is the oxyd of lead, usually supposed to be combined with acids, from which it may be precipitated by pure alkalies, as a white hydrated oxyd, from which the water may be expelled by strong heat. This white hydrated oxyd, like massicot, contains about 7 per cent. of oxygen. Dr. Thompson supposes that litharge is this oxyd of lead, mixed with a little carbonic acid obtained from the carbonaceous matter burnt in the refining furnaces, where litharge is made: but as yet, I hold all this to be probable conjecture only. We do not yet know the precise state of oxygenated lead that constitutes litharge. 3dly, Red lead, which contains from 10 to 11 per cent. of oxygen. 4thly, The brown, puce-coloured (flea-coloured) oxyd, containing from 13 to 14 per cent. of oxygen.

The puce-coloured or brown oxyd, is only made by the experimental chemist, by digesting nitric acid on red lead. The preparations of commerce among the oxyds, are white lead, massicot, litharge, red lead.

White Lead. This may be prepared several ways, viz:

1st, By corroding sheet lead with the fumes of vinegar, evaporated by the warmth of a hot bed of dung. This is the common process in this country.

2dly, By using for the same purpose, tanner's bark instead of dung, as the hot-house gardeners of Europe now do.

3dly, By exposing the vinegar pots to the same degree of heat excited by burning common fuel. This would be a much cleaner way of working; and in such a coal-country as Pittsburgh, I should think it would be full as cheap. The common heat of a stove-room, as used in England for converting cyder into vinegar, would answer very well as I think; and if not strong enough could easily be encreased.

4thly, By precipitating nitrat or acetat of lead by carbonated alkali. This makes a very white lead, but it does not absorb so much oil, or retain its colour so well, as white lead made in a common way.

5thly, By decomposing some of the neutral alkaline salts, as the muriats of potash and soda. I do not know whether the sulphats of potash and soda and the nitrats of the same alkalies have been used. Or whether, the muriats, sulphats, or nitrats of lime and magnesia would answer the purpose. The principle is the same, but there is full room for very important and valuable experiments; which probably will be the subject of a dozen patent rights; for in this country, if a man can contrive to eat his green peas with a four-pronged fork instead of a broad-pointed knife, he applies for a patent to secure the invention. For this mode of making white lead, Lord Dundonald has already obtained a patent. I greatly doubt whether he was entitled to it: for the process is very nearly that of Turner's mineral yellow.

I proceed then, to give an account of the common method of making white lead. Premising

1st. That it is necessary to set up the manufacture where good water is to be had in plenty: water containing hydrogenous, sulphureous or carbonaceous gas or salts, would spoil the colour.

2dly, It is desirable that fuel should be cheap, though this is not necessary: and that horse dung or bark should be of easy purchase.

3dly, There must be room and space for the manufacture. The person undertaking it in the common way, will need, at least, the following buildings:

A brewhouse for brewing vinegar from damaged grain.

A room for casting the lead into sheets; and for rolling it into spirals.

A smelting room, for recasting the refuse lead into blue lead again. These two rooms may be in one.

The casting room, the rolling-up room, and the smelting room should be contiguous, and may open into each other. The smelting room must be furnished with a fire place and chimney, and have a strong cast iron pan set in a brickwork furnace, to melt the lead. The rolling-up room should have a bench under the windows from one end to the other. All the rooms but the smelting room may be warmed by stoves.

A room for corroding the lead with vinegar. It should be of a good height, and the ground plan will depend on the quantity of business to be done. The stacks, or beds, may amount to six in height, more or less according to the size of the pots.

A room for holding the troughs, and grooved cylinders, where the white lead is scraped from the blue lead. In this room, a pump should empty the contents of the first trough into others, after the water is well agitated;

so that the finer part of the white lead may gradually subside.

A room that will hold one or two pair of good millstones, with the necessary machinery, to grind the white lead first *in water:* with the shoots, tubs, &c. and utensils requisite for this purpose.

A drying room, that requires to be moderately heated.

A room to hold whiting, with which white lead is always plentifully adulterated. When added in the proportion of 10 or even 12 per cent. the lead is not much the worse as a paint: but when mixed, as it usually is, to the amount of from 20 to 25 per cent. it causes the paint to adhere but slightly, and to peel off from the wood.

A room to hold millstones wherewith the white lead should be ground up with whiting and *oil*, to sell as paint ready for use. Much of the profit of an establishment may be made to belong to this department of the manufactory. These two mill-rooms might be worked with the same machinery; and the drying room, and whiting room should be contiguous.

There should also be a room separate to prepare and contain a stock drying linseed oil, to grind up with the lead intended to be sold as paint.

For this purpose, a stock of litharge, and sugar of lead will be wanted, which may be best kept in the whiting room.

A store room. A packing room. A counting house.	These apartments should be contiguous.

A cooperage and carpenter's room.

A lumber room.

Space for cart-ways, gang-ways, stabling, cart house, &c.

There will also be needed, in the common way, two

sets of cast-iron rollers, one fluted lengthway, and another crossway.

It is true, a manufactory may be carried on with fewer apartments, but very few of those I have mentioned can be dispensed with, in a manufactory on a tolerable scale. It should not be commenced under ten or twelve thousand dollars. Although white lead is a cash article, yet it must be remembered that blue lead is a cash article also, and the stock on hand will be of considerable value in a small compass.

Such an establishment ought to have a red lead manufactory connected with it: and by and by, the manufacturers here will find their interest in connecting with it, a manufactory of sugar of lead, and of pyroligneous acid.

The buildings will require *at least* 12,000 square feet on the ground plan. The power may be water power, horse power, or a steam engine.

Of Casting the Lead.—A man stands with a barrow, at the left hand of the smelter who also casts the lead into plates. He has two long ladles, one to lade out the melted lead, the other with a flat bottom, thirty inches long and six inches broad. Holding in his left hand the flat ladle, he pours on it from the other ladle in his right hand, (resting it at first on the edge of the pot that holds the lead) a quantity of melted lead, moving the right hand ladle down to the point of the left hand ladle, and gradually discharging its contents. Great part of the lead, runs off and falls on a table ready to receive it, but a part remains in the left hand ladle, covering the bottom thereof with a sheet of the above dimensions and about the eighth of an inch thick. The smelter, turns this off into the barrow, which when full, is wheeled away to the rolling room, and discharged upon the roller's bench, who turns it into a spiral of about three and a half inches diameter.

The top and bottom of the spiral roll, are kept as even as possible, that the cover may cover them closely and accurately. Sometimes sheets of lead are used flattened mechanically (milled) between two rollers: sometimes, a caster having melted lead poured into a case of the size of the proposed sheets, draws it into sheets by running a sliding piece of wood quickly along the edges of the frame or mould, and pushing the melted lead before it, thus forms it into a sheet.

The lead is then ready to be carried into the *corroding* room.

This room, is furnished with earthen pots which should be of stone-ware. They should be wide enough at top to hold a spiral roll of lead, which must rest on a ledge within side the pot about one-third or half of the way down: the pots may conveniently hold from one to three quarts of good vinegar, according to the size of the spiral which fills the top. The smelter or caster, making his sheets according to the size of the pots which the manufacturer thinks it convenient to use. The vinegar just reaches the under side of the ledge on which the spiral roll stands. The pots are placed on a layer of about three or four inches of horse dung, not quite close to each other all round the room, leaving a gang way in the middle. The lowest tier are then imbedded up to their necks in fresh horse dung, or tanner's bark. A piece of lead is then placed on the top of each spiral roll, and is then covered with a broad board. On this board another layer of dung with its pots, vinegar and spirals of lead is placed and buried up in dung or bark: and so on, as high as will admit of convenient management. The top tier, should be well bedded in dung and covered, because, it answers best to be examined from time to time to shew when the vinegar is all evaporated, which usually takes place in about two months. This top tier should be well

bedded in dung, that it may be a fair specimen of the general progress of the pots throughout the under tiers, which cannot be got at so easily. The stacks are taken down when the vinegar is evaporated, and the lead is carried into

The mill room. Here, the hardest, whitest, and most sonorous pieces of lead, are picked off and selected for the pigment usually as flake white; which is generally pure white lead unadulterated: and which may therefore serve as a comparison to ascertain the quantity of adulteration in common white lead.

The corroded plates are then run through the grooved rollers, and scraped. This is a very unwholesome part of the process. The men concerned in it, become paralytic in three or four years. An improvement has been made by a Mr. Archer Ward, in this part of the manufacture, which, although Dr. Coxe has copied it in the second volume of his series of the Emporium, and Mr. Cutbush also has copied it in his useful work entitled the American Artists Manual, yet, as I do not wish to send my readers hunting after processes to be found in other books, I chuse to copy it also in this. My plan being to accumulate all the useful information I can upon each subject, in one connected view: I am therefore not deterred by now and then a little repetition, or the insertion of papers which other works have stolen, before it came to my turn to pillage the rich store-houses of European information.

Mr. Archer Ward's account of his improvement is as follows.

Description of a method of preventing injury to the health of the workmen employed in preparing White Lead. By Mr. Archer Ward, in his own words:

IN order to explain, as well as I can, the advantages that will accrue to the workmen by adopting my inven-

tion, in preference to the common mode of preparing white lead, I will first state what the common mode is. When blue lead is in part corroded in the stacks, by an acid raised by a considerable degree of heat, brought on by horse-litter, the corroded and uncorroded lead are taken from the stacks to a room, called the engine loft, where a pair of iron rollers is fixed with a screen under them. The lead in this state is passed through the rollers and screen; from the motion of these rollers and screen, by which the white lead is separated from the uncorroded or blue lead, together with the moving the lead, in order to its being passed through them, a very considerable quantity of fine dusty white lead is raised, which almost covers the workmen thus employed, and is very pernicious to them. And not only in this part of the process are they liable to be thus injured, but they are again exposed to the dusty lead, by removing the blue lead from the screen-house to the furnace, as there still remains a quantity of the fine particles of white lead, which of course rises in removing it; and also, in removing the white lead from under the screen to the grinding-tub, a quantity of the dust arises, which is very detrimental to the people so employed.

My invention removes all these difficulties respecting the dry dusty white lead, so very injurious to the health of the working people; and consists of a vessel, as shewn in the plate,* fig. 1, twelve feet long, six feet wide, and three feet ten inches deep. In this vessel is fixed a pair of brass rollers in a frame, one roller above the other. The centre of the rollers is about ten inches below the top of the vessel; and, one inch lower, is a covering of oak boards or riddles, an inch thick, fixed in the inside of the

* See the next number.

vessel, in a groove, so as to be taken out occasionally; these boards are bored, with a centre-bit, as full of holes as may be, without danger of breaking into each other; the size of these holes is, in the machine at large, about five-eighths of an inch in diameter. This being done, the vessel is filled with water, about three inches above the oak boards or riddles; the lower brass roller is now under water, and about half of the upper roller is under water also. Thus the lead coming from the stacks, is put through the brass rollers in water, and, by raking the lead with a copper rake, over the oak boards or riddles, the white lead passes through the riddles, and the blue lead remains above; which, being taken out, is thrown upon an inclined plane of strong laths to drain, where it remains about 12 hours, when the blue lead is ready for the furnace to be re-melted; by this means no dusty white lead can rise in any part to the work-people. No such plan as this (though long desired) has, to my knowledge, been put in execution, so as to answer all the purposes above stated. It may be asked, why the lead in the common mode, is not made wet before it is passed through the rollers and screen. Should this be done, the lead would be a paste on the rollers and screen, and the white lead prevented separating from the blue lead, which is absolutely necessary in the preparation of white lead.

Reference to the Figure.

Fig. 1, A, an inclined plane of wood, on which the white and blue lead is placed immediately from the stacks, and thus introduced between the brass rollers BB.

CC, the vessel containing water.

DDD, the pierced oak boards or riddles, which, by being made to slide in grooves in the sides of the vessel CC, may occasionally be taken out by removing the wooden bar *ee*.

E, a handle or winch, which, in the machine at large, may be a wheel communicating to mill-work, and thus turn the rollers BB.

F, a pinion, fixed on the gudgeon of the upper roller, and communicating with a similar pinion on the arbor of the lower roller, keeping both of them in motion by the turn of the handle. As it is necessary that the upper roller should be at liberty to rise or fall, in order to give a due degree of pressure to the lead in passing between the rollers, two weights GG, with proper stems to them, are placed over the gudgeons of the upper roller, thereby keeping a due degree of pressure; and, if any piece of the lead should be thicker than usual, admitting the roller to give way to it, and thereby preventing any injury to the machinery.

H, a notch in one side of the wooden vessel, serving to regulate the depth of the water on the riddles DDD.

The foregoing description is accompanied by two certificates; one from Mr. Samuel Walker Parker, stating that many tons of white lead have been made, in the manner above described, at the manufactory at Islington, belonging to Walker, Ward, and Co. and that, since Mr. Ward's plan was adopted, no other method has been used. The other certificate is from Mr. H. Browne, of Irongate, Derby; who says, that he thinks the foregoing invention a very valuable improvement in preparing white lead, and that the quality of the lead is not in the least injured by it.

Mr. Wetherill, of Philadelphia, obtained a patent for a somewhat similar contrivance."

The white lead, thus being scraped and rolled off from the blue lead, the latter is sent back to the smelting room, and the white lead agitated in water, then pumped up into other troughs to drain: the refuse of the first troughs is also conveyed to the smelting room.

When the white lead washed and drained, is of a pasty consistence, it is well ground between two mill-stones, and from the troughs that receive it, is carried to the drying room to dry upon porous pans. When whiting is mixed with it (which is always the case) the whiting ought to be well washed in troughs to carry off the dirty part: then it ought to subside, and the water drained away. Then it should be washed again for the coarser and sandy parts of the whiting to subside, and the finer parts of the whiting only should be taken, and a second time (after being mixed with the white lead as well as possible in the troughs) passed with the lead in a state of mixture through the mill-stones. Then dried together in the stove room.

From the stove room, the lead is conveyed to the store room, and thence to the packing room.

Such is the common method of making white lead; a process sufficiently complex, troublesome, and unscientific. The substitution of tanner's bark for dung, is an improvement in respect to cleanliness, but I do not know that it is superior in any other way.

The substitution of a stove, whose flues might be conveyed among the pots, or the heat of the room kept up to the necessary degree, regulated by two or three thermometers, would in my opinion be a considerable improvement.

But when I went through the vinegar manufactories of England, I was struck with the obvious application of the processes there used, to the manufactories of *white lead* and of *verdigrease*: and I propose it without hesitation to the manufacturers here, as a combination of processes that cannot but prove economical and lucrative. I do not expect however that it will be put in practice, till on reading this, some speculator in patent rights, will take out a patent for it, and swear in the usual way that he is the true and original inventor. I have already detailed a process

of bleaching by means of red lead, so easy, so speedy, so practicable, and so economical, that no one who has tried it, would hesitate for a moment to prefer it to the bleaching by manganese, even if the latter substance could be obtained for nothing. I have had bleached under my own inspection by this process, more goods in a week, than any manufacturer of cotton goods of whatever species in this country, manufactures in a year. Yet bleaching by manganese, imported at an extravagant rate from Great Britain still continues in use, even among the best informed manufacturers of cotton articles in this country. However as the process is my own, I now give notice that I will take out a patent for it; and then perhaps, it will be thought of some value, when some value is paid for the liberty of using it. Having turned my attention early, to anatomy and physiology, and to medicine also, as well as chemistry, I have for many years practised among my friends, among the poor, and wherever my neighbours of the medical profession thought fit to consult me upon any case, curious or difficult. But as I have never directly or indirectly accepted any thing in the form of a fee for my trouble, I am frequently obliged out of sheer good will to my patients, to advise a physician to be called in because my prescriptions really do no good for want of faith in their efficacy, until the patient has to pay for them. Some physician of eminence in England, I forget who, is said, always when he took medicine for his own indisposition, first of all to take a guinea out of his right hand pocket and put it into his left hand, as a sum to be religiously spent in some act of charity; otherwise he would have doubted the efficacy of his own advice. Indeed it is true universally, that the world never feels grateful to those who benefit them gratis: they only are respected, who setting a proper value on their services exact the highest price for them. People take for granted from an intimate

knowledge of their own dispositions, that you would never give, except what was of little worth. If you set no value on your own property, what obligation is there on the public, to consider it as valuable? I forgot to mention that in my patent for bleaching, I mean to include the manufacture of white lead, as connected with it. I know of no means so proper to make the process of value to the public, and introduce the use of it.

But to my immediate purpose. The process of making white wine *vinegar* in England is as follows.

In an oblong room heated by stoves to the degree of about 80 of Fahrenheit, place upon tressels a series of quarter casks, high enough from the floor for a pail or tub to stand conveniently under the casks, from which the liquor is drawn. The top of the quarter casks is pierced full of auger holes. The casks are filled with cyder. On the top of the casks, is placed a tub full of Malaga raisins, the bottom of the tub being likewise pierced with auger holes. A man is employed from morning to night, in going round this series of quarter casks, and drawing from the bottom of each, a pail or bucket full of cyder, which he pours on the top of the Malaga raisins. The cyder percolating through the body of the Malaga raisins, acquires a saccharine mucilage, together with a vinous flavour; and by degrees is converted into vinegar. The raisins may be employed with a little addition to give flavour to two casks of vinegar. When the cyder is thus converted into vinegar, it is drawn off, and the casks being replenished with cyder, the same routine is again pursued. The vinegar is fined with white of egg, racked off, and is then ready for sale.

During the percolation of the vinegar through the Malaga raisins, so much acetous acid evaporates and is wasted, that if plates of sheet lead or copper were hung up in the room, a manufacture of white lead or of verdigrease,

would be established to a considerable extent and at no expence. When I suggested this to a vinegar manufacturer in Gloucestershire, whose works I examined, he promised to give it immediate trial; but I left the country without an opportunity of knowing whether he did so or not.

I have already mentioned, that the process of making carbonat of lead, by precipitating the nitric or acetic salts of lead, by carbonat of potash, although the article be very white, is too dear for a manufacture in the large way. The carbonat of lead thus made, on an average of the experiments of Bergman, Berthollett, Klaproth, and Chevenix, consists of 84,13 lead, and 15,87 acid. But the carbonat of lead can be made by treating the sulphat and muriat of lead, which, form the refuse in my mode of bleaching, with carbonat of potash; a process which belongs to, and is part of the process, I claim to myself; and which, until I procure a patent for it, any one is welcome to use.

I come now to the neatest, most scientific, and most economical method of making white lead, founded upon Lord Dundonald's patent of decomposing the muriat of potash, by litharge or any oxyd of lead. To make this perfectly intelligible, I must go back to the history of *Turner's mineral yellow;* the common, heavy, hard, fused, patent yellow of the colour shops, and in common use with the coach-makers and chair-makers. Turner took out a patent for making this colour about eight and twenty years ago, which being contested, was set aside, owing to the gross ignorance on the subject, of the Court of King's bench and the bar.

Turner, by a mill-stone rolling vertically in a circular trough, triturated for 12 hours together in the form of a paste, two parts by weight of common salt, and one part of litharge. He would have done better by three parts of

common salt as I think. By degrees, and by remaining together for twelve hours more, the common salt became decomposed; a muriat of lead was formed, and pure soda, the basis of the common salt. The pure soda was drained first and the remainder washed away, and boiled down to chrystallize, in a room where charcoal was burnt in braziers, to supply carbonic acid gas. The pure soda would not decompose the muriat of lead, there being only *one* divellent affinity, viz. that of soda.

The lead thus freed by washing from the soda, was put into crucibles and fused in a strong heat. It then became a yellow chrystallized mass, the patent yellow of the shops. The soda when chrystallized, was disposed of as carbonat of soda.

Now, if the soda, instead of being washed away, had been left quietly to gain from the atmosphere or elsewhere its carbonic acid, being still in contact with the white, moist, muriat of lead, there would have been *two* divellent affinities, and a double decomposition would have taken place: the carbonic acid would unite with the lead, while the muriatic acid would again unite with the soda, reproducing the original quantity of common salt, which might be washed away, re-chrystallized, and used again for the same purpose. The carbonated lead thus produced would be *white lead.*

Lord Dundonald discovered, that although common salt and various other alkaline neutrals would answer the purpose, the decomposition went on best with muriat of potash, instead of muriat of soda. And in this way is the greatest proportion of English white lead now made.

In England, the making of white lead, is connected with the manufactory of soap; almost all the alkali now used for soap being procured from the decomposition of neutral alkaline salts by means of oxyds of lead. For by thus procuring them, the expence of rendering the ley

caustic by means of quicklime is superceded, and the trouble and expence greatly economized.

I prognosticate, that whoever will commence in this country, the manufacture of white lead connected with the manufacture of cyder-white-wine vinegar—or the manufacture of white lead by the decomposition of alkaline neutral salts, connected with the making of hard soap—will, if there be sufficient capital, skill and industry, make a profitable concern.

We have no business in this country when peace comes, to import lead from England. The Louisiana country is amply sufficient to supply all our wants: and ere long, the atlantic states will be supplied from thence not merely with blue lead, but with red lead, massicot, litharge, white lead, and shot; for all which, the materials and conveniencies of situation are abundant in that country.

To the Editor of the Monthly Magazine, May, 1809.

Sir—I am informed that, in consequence of an alteration (lately made) in the process of drying *White Lead*, the health of the labourers, in an extensive manufactory in the neighbourhood of London, has been very materially benefitted—the fatal *constipation of the bowels*, so common amongst them, having much decreased, which is attributed in a great measure, if not entirely, to this alteration. The different mode of drying the lead adopted is (if I understand the matter right), that instead of laying it on chalk, it is now poured into earthen-ware pans, and left to dry in them; the lead does not undergo nearly so much handling as before, and the fine particles of it, which used to float in great abundance about the room, are not perceived in such dense clouds as they used to be; this dust entering the mouth was one principal cause of the diseases to which the workmen were liable. By means of your miscellany, I wish to give publicity to the

above circumstance; and should any of your readers be able and willing to give me any further particulars respecting this manufacture, which may be conducive to the health of those employed in it, they will much oblige

A CONSTANT READER.

Mr. John Brierley's (Greenfield, Flintshire,) Patent for a new mode of setting Blue Lead for corroding the same into White Lead.

THIS method, by means of a bed of dung or bark, into which are inserted pots filled with acid; over these are placed boards having holes bored in them to admit the vapour of the acid round the rolls of lead. On these another bed of dung or bark is placed, and the process repeated before, forms a second bed; these beds may be repeated to any practicable extent, and are denominated a stack. There is a chimney or flue running through all the beds, for the purpose of distributing the vapour of the acid equally through them all, for which purpose that part of the flue, which extends from the one bed of dung or bark to the other, is left with small interstices between the bricks, so as to communicate any superfluous vapours above or below, or carry off to the other bed any vapour which may be to spare in that bed.

The observations of the patentee refer 1. To the number of pots, and the difference as to the expense of them. 2. To the health of the manufacturers. 3. To expenses of the annual breakage.

With respect to the 1st. According to the above plan a bed may be set with 280 pots of equal effect with a bed, which, according to the old mode, would require 560 pots, making a difference of one half. The pots used in the plan cost 2d. each; those in the old method 5d. each. So that 280 pots at 2d. each will cost 2l. 6s. 8d. and 560 pots at 5d. will cost 11l. 13s. 4d. leaving a difference in

favour of the plan of 9l. 6s. 8d. for each bed. Now if a stack consists of seven beds, and the manufacturer raises nine stacks, the gross amount of the saving, in the first instance, will be 588l. According to this plan the manufacturer can set three tons of lead in a bead, when in the old way he can only set about 1 ton 12 cwt.; and the corrosion is more certain, from the fumes of the acid having free access to all the lead, which is placed upon the boards, instead of the rolls being confined separately in the pots along with the acid; that the pots, which are placed under the joints of the stack-boards, will be filled with liquor or acid neutralized by being mixed with the ooze in the bark, and the fumes arising therefrom being condensed, the pots become filled, and the necessary corrosion is therefore prevented. From this mode of setting lead, the manufacturer will obtain a third more of white lead than according to the old way.

2dly. The plan clearly demonstrates, that the rolls of lead being placed upon boards are easily taken off when corroded. When the stack boards are removed, the rolls should be well sprinkled with a watering can, which will prevent the dust from rising and annoying the labourers. Now, according to the old way, if the lead is well corroded, the expansion becomes so great as to fill the pots tight and close, and the labourer, in order to disengage the ceruse from the pot, is obliged to knock it upon the taken-off boxes, which causes a dangerous dust to arise, that affects the labourer with that most dreadful disorder, the colic of minerals*.

3dly. The breakage of the pots according to this plan, is not as one pot to thirty in comparison of the breakage arising from the mode of setting. For experience tells us, that in the old way, we may expect a loss of 30 pots in 560, and of course in a stack 210, and in 9 stacks 1890 pots. Supposing the manufacturer to take up and

* Colica pictonum. Colic of Poictou, and Devonshire.

set four rounds of stacks in one year, the number of pots broken will be 7560, which, at 5d. each pot, amounts to 157l. 10s. These nine stacks of pots in the old way would cost 735l.; according to the new plan only 147l. leaving a difference of 588l. as stated under the first head of observations. Exclusive of the savings before enumerated, it must be of very great benefit to the manufacturer that he can bring into the market, in the same given time, a third more of white lead by pursuing the plan before specified, than by the old modes.

27 *Month. Mag.* 331 *and* 588.

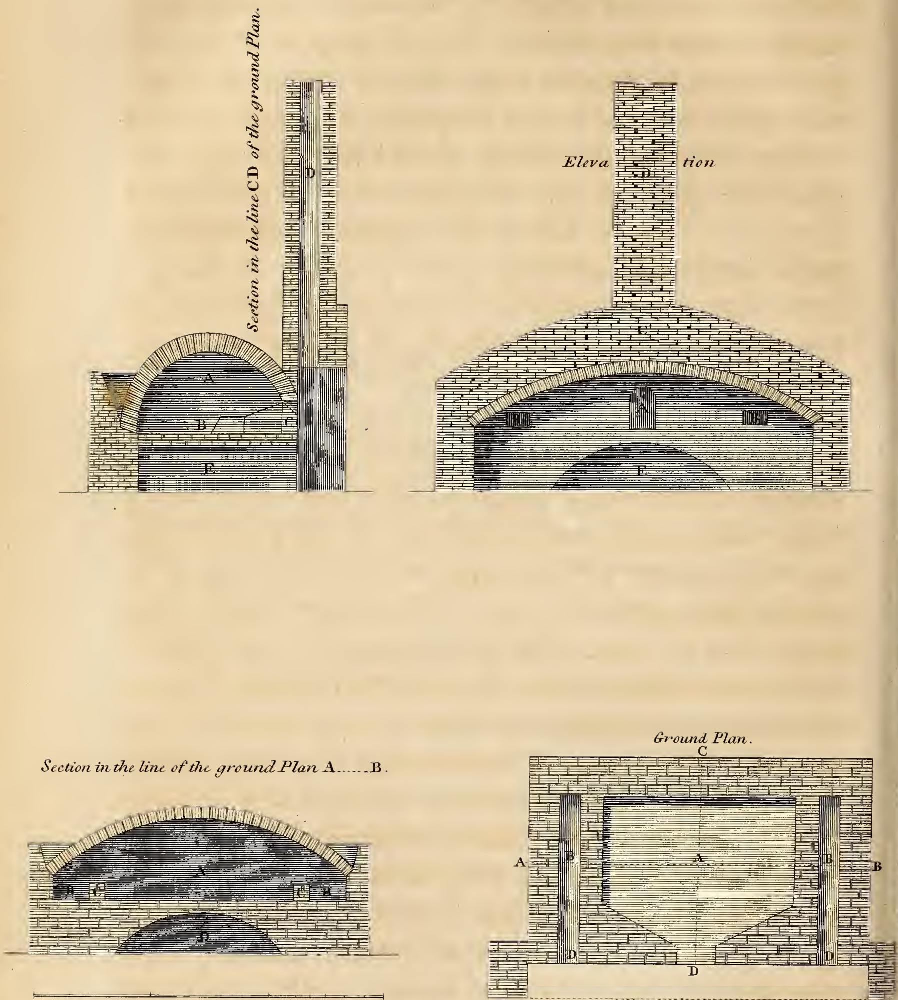
RED LEAD.

I PROCEED now to the manufacture of *Red Lead* and massicot; but I must defer the plate I propose to attach to my account of this manufacture to the next number, the present being supplied with the usual quantity, and not being able to procure in time the engravings necessary to illustrate the subject of lead.

The following account of red lead from the excellent Essays of Bishop Watson (of Landaff) is proper to introduce the subject.

"IF the reader does not know what *minium* or *red lead* is, I would wish him to send for a few ounces of it to his painter or apothecary. Supposing him to have a parcel of red lead before his eyes, the first thing which will strike him is its vivid colour verging a little towards orange; if he crumbles it between his fingers, he will find it to be an almost impalpable powder; if he poizes it in his hand, he will perceive it to be much heavier than either brick dust or red ochre, with which substances it is sometimes adulterated; if he compares it with a piece of lead, he will be astonished how it can be either produced

Red Lead Furnace.



H. Anderson sc.

from lead, or be capable of being, by a very slight operation, *reduced* into lead again.

It has been mentioned in the preceding essay, that red lead is made from *litharge* at Holywell: this red lead, which is made from litharge, is not perhaps, in all its properties, of quite the same kind with that which is made directly from lead; at least I have been informed, that the makers of flint glass, who use much red lead in the composition of that glass, are of opinion, that the litharge red lead does not flux so well as that which is made from the direct calcination of lead, as is practised in Derbyshire. There are in that county nine red lead mills or furnaces, all of which are much upon the same construction.

The furnace is very like a baker's oven, its vaulted roof is not a great distance from the bottom or floor, on each side of the furnace there are two party walls, rising from the floor of the furnace, but not reaching to the roof; into the intervals, between these walls and the sides of the furnace, the pit-coal is put, the flame of which being drawn over the party walls, and striking upon the roof, is from thence reflected down upon the lead, which is placed in a cavity at the bottom, by which means the lead is soon melted. The surface of melted lead, when exposed to the open air, instantly becomes covered with a dusky pellicle; and this pellicle being removed another is formed, and thus by removing the pellicle, as fast as it forms, the greatest part of the lead is changed into a yellowish green powder. This yellowish powder is then ground very fine in a mill, and being washed, in order to separate it from such parts of the lead as are still in their metallic state, it becomes of an uniform yellow colour, and, when it is dried to a proper consistency, it is thrown back again into the furnace, and being constantly stirred, so that all its parts may be exposed to the action of the flame of the

pit coal, in about 48 hours it becomes *red lead*, and is taken out for use.

The colour of the red lead admits some variety, which is occasioned by the different degrees of heat. If the heat is too small, instead of red it is yellow or orange coloured; if it is too great, the red colour is changed into a dirty white, between these two extremes it is subject to some diversity of shades of red, which cannot be well noticed or described, except by those who are engaged in the making of it.

It has been asserted, that the reverberation of the flame and smoke upon the surface of the lead, is not a necessary circumstance in giving it a red colour, but that it will acquire this colour by a long calcination without coming into contact with the flame. The truth of this assertion I think may be doubted. I have more than once calcined lead for above 60 hours, without suffering the flame of the fire to touch it during any part of the process, but by this method I could never obtain any thing better than a dirty red, resembling the red of brickdust, which is very different from the colour of red lead; and even this dirty red was changed into a yellow colour, by augmenting the degree of heat with which the lead had been calcined. The method of making red lead is very well understood in England and Holland, but not in France; and the French workmen are of opinion that it cannot be made by the flame of wood fires.*

During the making of red lead, part of it is volatilized, there rises up from it a vapour, which attaches itself to the roof of the furnace, and forms solid lumps. These lumps are of a yellowish white colour mixed with pale green and some reddish streaks, wherein are frequently small red crystals, resembling such as may be artificially form-

* Mem. de l'Acad. des Seien. 1770. Elemens de Mineral, par M. Sage. Vol. 2. p. 248.

ed by subliming sulphur and arsenic together. The workmen call the whole of what is separated from the lead in the form of smoke, sulphur: when this sublimed matter is detached from the roof of the furnace, the red parts are converted by a subsequent process, into red lead; and the yellow ones are sent to the smelting furnaces, to be run down again into lead. The quantity of this sublimate amounts to about five hundred weight in making one hundred tons of red lead. The proportion here assigned is not wholly to be relied on, since the smoke arising from the lead forms itself into larger masses, and in less time, when it is not constantly swept from the roof of the furnace than when it is; and the workmen endeavour to keep the roof as free from it as they can, because a small portion of it injures the colour of a large quantity of the red lead with which it happens to be mixed.

A ton or twenty hundred weight of lead generally gives twenty-two hundred weight of red lead, notwithstanding the loss of substance which the lead evidently sustains from the copious smoke which arises from it during the operation." [3 *Watson* 337.

The method of making red lead in England: from Jar's Voyages Metallurgiques, vol. 2, p. 569. There are two manufactories of red lead in Derbyshire, at Chesterfield and at Worksworth. The furnace appropriated to this operation is a reverberatory with two fire places under one and the same arch, which are separated from the floor in the middle of the furnace by a wall on each side about 12 inches high. Each fire place is about 15 inches wide, and runs the whole length of the furnace from the front to the back or about 9 feet. The distance between the fire places on each side is about ten feet. The mouth or front opening of the furnace is about 19 inches by 16 in height: neither this opening, or those of the fire places on each side of it are ever closed. They are all situated under a

high chimney, common to them all, and opening inside; so that the furnace is in fact a common baker's oven, of which, the bottom by two walls running the whole length of the arch, is divided into three parts; the middle being the hearth on which the lead is placed, in size about 10 feet by 9 feet, the other two parts on each side being fire places of which the dimensions are 9 feet by 12 inches and 15 inches. These fire places have neither grate or ash hole. The coal in middling sized lumps is thrown into these fire places, which it fills to the level of the side walls (that is 12 inches high.) The hearth is accurately and neatly laid with fire brick, with very small joints and is perfectly level. The hearth is common, extending from the springing of the arch on one side, to the springing of the same on the other,

About fifteen hundred weight of lead is the common charge of the furnace, of which about one-tenth is slag-lead, (procured by working the slags over again). The workman begins by forming a ledge just inside the mouth of the furnace, of the yellowish slag or refuse of the washing of the red lead of the preceding charge: this serves to keep in the melted lead during the operation. The flame from the coal fire on each side strikes against the roof of the arch, and is reverberated downward on the surface of the metallic lead on the hearth. During all this time, a man standing in front of the furnace, rakes the melted lead with an iron rake which is suspended by a chain hung on the outside of the mouth of the furnace, so that the man's hands are freed from the weight of the rake, and he has nothing to do but push it backward and forward. As the oxyd forms, he draws it to one side leaving the centre of the hearth filled with melted lead, of which by the rake he continually exposes fresh surfaces, until the whole is converted into a dusty oxyd. This requires from 4 to 5 or 6 hours. The whole of the

lead however, is not converted into oxyd. There are always some refractory lumps remaining, which are collected, melted over again, and worked up in the next charge. (These are probably parts of the lead, alloyed with silver, zinc or antimony, or all three.)

The fire is well kept up during the whole time; but as the mouths of the furnace and also of the fire places are kept constantly open to expose the surface of the lead to the air, the heat never exceeds a full cherry-red. The smoke and dust passes up the chimney situated over the mouth of the furnace.

At the end of about 5 hours the lead is converted into grey ashes, but it takes a continued heat of about 24 hours to convert it into massicot; during this time, it is raked just enough to prevent its clotting, and forming lumps, as well as any tendency to fusion. It is then raked out upon the floor of the apartment which is well and neatly paved with hard brick. In this state while on the floor, it is wetted with water and raked; and when cold it assumes the colour of yellow ochre. In this wet state it is taken away and ground between two mill-stones. But this operation does not grind it fine enough. Hence, after it has been discharged from the mill-stones into the tub placed to receive it, a man takes it up in a copper basin, and agitates it under water in another vessel, until by turning the basin round backward and forward in a half circle, all the fine part is washed out of the basin and falls into the tub of water, while the coarse sediment in the basin, is thrown aside, either to be ground or remelted. It is this sediment which is employed to form the dam or ledge in front of the furnace, used to keep in the charge of melted lead. The massicot so ground and washed, subsides; the water is turned off from it, and it is then carried to the furnace again for the next operation. Some manufacturers use the same furnace; others more con-

veniently have another furnace of the same kind for the conversion of massicot into minium or red lead.

The yellow sediment is now carried to the hearth of the furnace : the fires on each side are lighted, and kept up as before. As the coaks or cinders form, they are raked out and fresh coals put in. The yellow oxyd is now stirred only often enough to keep it in a separate and powdery state, and very gradually to expose fresh surfaces to the air. In from 40 to 48 hours, the yellow colour gradually disappears and is converted into a deep brownish red. (This is in my opinion the puce coloured per-oxyd of lead.) But when cold, this brownish red, passes into the bright red of the minium or red lead of commerce. When taken out of the furnace, it is spread over the surface of a large box to cool. It is then passed through a sieve in a close vessel, to prevent loss, and collected for sale.

The coal used should be but moderately bituminous, evidently because the carbonaceous smoke retards the oxydation. The coaking, Newcastle coal, is usually preferred in England. They are persuaded that red lead cannot be made with wood. It may be more difficult, partly on account of the smoke, and partly on account of the acid vapour of wood unless it be very dry. Certainly red lead cannot be made by applying the heat externally : it must be applied to the surface of the lead.

I shall give a plate of the red lead furnace in my next.

The *litharge* of commerce is the refuse of the refining furnaces, although it can be made also in the red lead furnaces. The lumps of lead that cannot easily be converted into oxyd, might as I think be advantageously thrown aside, for refining ; the silver, if they contained it, would doubtless be an obstacle to the oxydation. Litharge, seems that state of lead, best adapted to the decomposition of alkaline neutrals ; but I do not know that Dr. Thompson's opinion has been established, that it is in any degree

a carbonat of lead, though the rationale of the process by which it is made, would point out the formation of the carbonic acid, during the process of refining lead.

By accident I mislaid the following important memoir on the refining of lead and the making of Cupells or Tests. It is from the Journal des Mines, No. 64.

Memoir on the Refining of Lead; with some reflections on the inconvenience of Ash Cupells; and the description of a new and economical method of constructing Cupells or Refining Vessels: read in the French National Institute. By C. Duhamel, *Member of the Institute and Inspector of Mines.*

It is well known, that to separate silver from lead, a metallurgic process called refining or cupellation, performed in a vessel called a cupell, has been employed: it is known also that this vessel is composed either of the ashes of the bones of animals, or of those of vegetables, after they have been lixiviated, to free them from the saline matters which they may contain.

The great quantity of wood-ashes which must be employed in the construction of cupells, and the difficulty of obtaining them, long ago induced me to endeavour to discover a simpler and less expensive method of constructing the vessels in question. The old chemists having observed that lead becomes oxydated, or reduced into what is called *litharge*, when exposed to heat, or the contact of the atmospheric air, while the silver united to it retains its metallic form, nothing seemed necessary but to find the means of separating these two metals. They were conducted to the method of accomplishing this by observing that the oxyd of lead, in its state of liquefaction, easily penetrates the substances which are in contact with it, and especially bone-ashes, without deforming the ves-

sels which are formed of them. No matter, indeed, is more proper than the latter for constructing small refining cupells.

The difficulty, and often even the impossibility, of obtaining about 160 English gallons of ashes for each operation of refining on a large scale in the German furnaces, made the proprietors have recourse to wood-ashes; but, besides that these ashes are expensive, it often happens that they cannot be procured in sufficient quantity. They are even attended with one inconvenience, which is, that they come off, and float on the fused lead; the refining then fails: and this takes place every time that the ashes are badly prepared, that the cupell is insufficiently or not uniformly beat, or when the canals destined for the evaporation of the moisture are neither in sufficient number, nor properly arranged, nor covered with a stratum of scoriæ, on which is established the bottom, that receives the ashes, and which ought to be constructed of the most porous bricks, in order that the water, with which it is necessary to moisten the ashes, may penetrate them in evaporating, may proceed to the bed of scoriæ, and escape by the spiracles which are at the base of the furnace.

To ascertain the proportion of lead in silver, it is sufficient to put some pennyweights into a small cupell of bone-ashes placed under the muffle of an assaying furnace. In proportion as the lead becomes oxydated, it insinuates itself into the cupell, and the silver at last assumes that vivid appearance which announces that the whole lead is dissipated, that the silver it contained is refined, and has attained to its *maximum* of purity.

In refining on a large scale, the object also is to separate the silver from the lead, but not to make the whole of the latter penetrate into the cupell, which is even impossible; for in that case it would be necessary to have a much larger quantity of ashes for the total absorption of

the metal: besides, the operation would require a period ten times as long as that used in general for refining, and would occasion ten times the expence in fuel, and a much greater loss of the metals than by the usual process, where the greater part of the lead is obtained in litharge, while a portion penetrates into the cupell for about two inches of its thickness, which must be fused to revive the lead. This reduction is also more expensive, and experiences a greater loss than the litharge, which is easily fused, and which, without passing through the furnace, may be employed as an article in commerce.

Lead ore and litharge may be fused as in England, and the department of the ci-devant Brittany, in a reverberating furnace the soles or basons of which are formed of pounded and moistened clay. These soles can stand the action of heat and of the oxyd of lead for six or eight months of uninterrupted labour.

The durability of these earthen soles gave me the first idea of the method, which I shall hereafter propose, for refining-furnaces, where the only thing required is to oxydate the lead to obtain it in litharge, and not to cause the cupells to imbibe the whole of it, as is done when the object is to assay the metal in order to know whether it contains silver. In operating on a large scale, the cupell, though of ashes, absorbs only a part of the lead, as I have already said, observing at the same time that it would be much more advantageous to obtain the whole transformed into litharge, the reduction of which into lead is much easier than that of the oxyd contained in the ashes, which oppose fusion, and the scoriæ of which always carry with them some of the metal.

In a cupell of ashes beat into an oval circle of iron, the greater diameter of which is only five or six feet and the less one yard, the English refine from a ton to 23 cwt. of lead, which is converted into beautiful litharge, except the

small portion which penetrates into the cupell, the thickness of which is only about 2 3-4 inches, and which is supported under the arch of the furnace by two bars of iron. A pair of leather bellows drive the litharge towards the anterior part of the furnace, from which it falls, without interruption, on the floor of the foundry, while, to fill up the vacuity left by the oxyd running off, an ingot of lead placed close to the base of the bellows is made to advance gradually into the interior part of the furnace. This lead, by fusing, keeps the cupell full till towards the end of the operation.

If I have here given a short view of the process of the English, it is only to shew that it is possible to perform operations of refining by employing only a small quantity of ashes for the construction of cupells. Those in question do not absorb 90 pounds of oxyd in the large quantity of lead which is refined.

It is then proved that metallurgists have always endeavoured to obtain the greatest quantity possible of litharge, and little ashes impregnated with oxyd; but as they thought that they ought not to deviate from the docimastic process, they have always constructed their cupells of ashes.

It has been seen that in cupellation on a small scale, lead, in proportion to its oxydation, penetrates the ashes. When no more is left, the small button of silver remains pure at the bottom of the bason under a spherical form. This operation takes place with the more celerity, as the surface of the mass is always convex in these small vessels; which allows the oxyd to flow as on an inclined plane, towards the edges of the cupell, where it is immediately imbibed.

The case is not the same with cupells on a large scale, which are several yards in diameter: bellows must be applied, the wind of which serves not only for accelerating

the oxydation, but also for driving the litharge towards the gutter formed for its escape.

We have remarked the inconveniences and even the impossibility of making the whole lead penetrate into the ashes of large cupells: oxydation, indeed, is not effected but in the parts of the mass exposed to the contact of the air or to the wind of the bellows; but as litharge, towards the middle of the bason, could not reach its edges, it would remain there in a state of stagnation, and would necessarily oppose the formation of a new stratum of oxyd. This has induced metallurgists to expel the litharge by the wind of a pair of bellows in proportion as it is formed, and to make it flow from the furnace.

Oxydation then take place only at the surface of the mass, and not at its lower part: if the case were otherwise, the ashes of cupells would be penetrated by the oxyd to a thickness the more unequal, as the operation is longer; but I have always remarked, that the *test*, or the part of the ashes impregnated with litharge, in refining on a large scale, is not thicker in the centre of the bason than towards its circumference, though the lead remains thirty or forty times as long in the bottom as on the edges; since the mass continually decreases till the whole lead is reduced to litharge, and till nothing remains but a cake of silver at the bottom of the cupell.

If the whole lead is imbibed by the assaying cupell, it is because this small vessel is exposed to a heat uniform in all its parts. As the cupell, in operations on a large scale, presents to the action of the caloric only its upper surface, the oxyd imbibed ceases to penetrate it at the place where the temperature is no longer high enough to keep that oxyd in a state of fusion. For this reason, the thickness impregnated is equal throughout the whole extent of the cupell; and this prevents the possibility of making the whole lead penetrate into the ashes.

From the above observations it may easily be conceived, that if the assaying of lead ought to be performed in small cupells of bone-ashes, in order that the oxydated metal may penetrate them, and be in part evaporated, the case is different with refining on a large scale, where it is necessary to accelerate the operation, and to obtain as much litharge as possible.

I have already said, that the wood ashes of which cupells are made for refining on a large scale are expensive; that very often a sufficient quantity cannot be procured; and that besides this, part of the ashes, and sometimes the whole, separate themselves entirely from the sole; which occasion a considerable loss. I shall add, that to give more weight and consistence to the cupells, it is often necessary to mix with the ashes a large quantity of sand; especially if the lead contains foreign substances, such as arsenic, cobalt, antimony, tin, &c. If the lead be only arsenical, after having separated the first scum, a quarter of a hundred weight of iron filings or cast iron turnings are now and then thrown over the whole surface of the mass. This iron, being lighter than lead, floats over it and absorbs the arsenic, after which the mass must be scummed: soon after, the litharge is formed without any obstacle. This method is employed in Saxony.

The necessity of adding sand to the ashes of cupells must have conducted to the discovery of the following means, which I shall here propose.

New Method of constructing Basons for Refining.

Without making any change in the mason-work of the refining furnace, called the German, care only must be taken to form at the bottom a sufficient number of canals for the evaporation of the moisture, and to arrange them in the manner best calculated to produce that effect. These canals or spiracles must be covered with a bed of

scoriæ, over which a pavement is to be made of one layer of the most porous bricks.

On this area, which must be concave like the sole on which the ashes of common cupells are beat, place founders' sand a little moistened; to which may be added a fifteenth part of argil, if it is not sufficiently earthy, in order to give it the requisite solidity; and the whole must be carefully mixed. This sand must be rammed in the same manner as for consolidating ashes; and a refining bason is to be formed in like manner, uniformly beat in all its parts. The thickness of this cupell must be six or seven inches: it may be formed of two strata, as will be seen hereafter.

After the bason has been uniformly beat in every part, about a gallon of lixiviated wood-ashes may be sifted over its whole surface, and rendered adherent with beaters.

When the cupell is thus prepared, let down the head on the furnace and make a moderate fire in the fire-hole; which must be maintained for several hours, in order to cause a part of the water, with which the sand has been moistened, to evaporate. The surplus will be dissipated during the operation, without any inconvenience, by canals of evaporation.

After a sufficient desiccation, raise the head and suffer the cupell to cool a little; spread out straw or hay over it, and arrange the ingots of lead, placing them gently on it that their weight may not derange the sand: it is to prevent such derangement that straw is employed, as is done in regard to cupells of bone-ashes.* When the quantity of lead necessary for filling the cupell is arranged in the furnace, let down the head, and, having luted it round

* Instead of prismatic ingots it will be better to cast the lead in hemispherical iron moulds. Pieces of that form are less liable to damage the cupell.

with soft clay, make fire in the fire-hole as for the common operations of refining.

When the lead is in complete fusion, and the mass is covered with scum and charred straw, make the scum or dross run off by the gutter for the litharge with a bit of board about a foot in length, in the middle of which is fastened a rod of iron of sufficient length to traverse the furnace and about a yard more.

When the lead has been well scummed several times, and begins to be red, make the bellows act, but at first gently; arrange the nozzles of them in such a manner, that the wind issuing from both may be directed to the centre of the cupell; and in order that the wind may be always reverberated on the mass, adapt to the extremity of each nozzle a small round piece of iron plate. This kind of valves, which the French refiners call *papillons*, is employed for refining according to the German method. They are suspended by hinges at their upper part: at each stroke of the bellows they are half raised, and they reverberate the wind on the lead, which accelerates its oxydation.

After all the dross or scum is removed, and when the lead has become exceedingly red, and covered with a stratum of litharge, form, with a small iron hook destined for that purpose, a small gutter in the sand of the cupell, which must be dug deeper, gradually and with caution, until the bottom of it be on a level with the mass. The litharge then, driven by the wind of the bellows towards the anterior part of the furnace, will run by this gutter and fall on the floor of the foundry, as is the case in the common operations of refining.

When the refiner observes that no more litharge remains in the neighbourhood of the gutter, he will stop the flowing off with a small quantity of moistened ashes: but as soon as the lead again becomes covered with oxyd,

the gutter must be opened, and must be dug in proportion to the diminution of the mass, taking care that no lead escapes, and particularly towards the end of the operation; for it would carry with it a great deal of silver, which would be lost. You must proceed in this manner till the silver has acquired its vivid colour; taking care to increase the fire in proportion to the diminution of the mass; especially when the operation is nearly terminated, because the silver then is collected together: and, as it is much more difficult to be kept in fusion than the small quantity of lead which remains united with it, it could be refined only in an imperfect manner at an insufficient temperature; and instead of about a twentieth of lead, which the silver generally contains in the German refining-houses, it would remain charged with a great deal more, which would render it more difficult to proceed to a second operation, called the *refining of silver*, by which it is carried to the required degree of purity. The Germans call this second process *silber brennen*, burning silver.

Those accustomed to the refining of lead according to the German method, will be able to perform that which I here propose; for, though the cupell be of sand instead of ashes, the operation must be conducted in the same manner.

It has been seen that the English refine a large quantity of lead in a small cupell: in the like manner, a great deal of metal may be made to pass by that which I propose, if care be taken to add more metal as that which is oxydated escapes. If we suppose that the cupell is capable of containing four or five tons of lead, above sixteen may be refined at one operation; which will not be attended with the inconveniences of the English process.

I have reason to think that a cupell of sand well constructed may serve for several operations without the necessity of re-constructing it each time, as is the case with

those of ashes; but in this case, and before the lead is introduced, you must fill up the gutter which has been made for the litharge to run off, after having removed with a chisel the kind of varnish which the oxyd of lead has left on the sides of it, in order that the new sand, somewhat moistened, may form an intimate connection with the old sand, which must also be watered in that part before the new sand is deposited.

The long duration of earthen soles in reverberating furnaces, where lead ore and even litharge are fused, as I have already mentioned, leaves no room for apprehension in regard to the action of the oxyd of lead, which will act only at the surface of the cupell, and will penetrate only a very small part of its thickness.

After one or more operations of refining, this crust must be removed, and fused in a furnace in contact with fuel, in order to obtain the lead. This process will be as easy as the reduction of that metal contained in the ashes of common cupells, and in a much smaller quantity. More litharge then will be obtained by the new method than the old; which is an advantage, as I have already observed. I shall here add, that as the sole of sand does not absorb so much oxyd of lead as that of ashes, it will not carry with it so much silver; for it is well known that lead revived from its ashes always contains more than that which arises from the reduction of litharge.

Instead of sand, argillaceous earth might be employed for the construction of cupells, as is the case in regard to the soles of the reverberating furnaces in the ci-devant Brittany; but it would be necessary to ram this earth repeatedly for several days; otherwise it would split, and these cracks would increase by the shrinking which must result from the heat, and lead would insinuate itself into these fissures: an inconvenience which cannot take place with sand even a little earthy. I shall observe also, that a

sole of earth would harden too much to allow a gutter to be dug for the passage of the litharge: in this case it would be necessary that the place destined for the oxyd to run off should be constructed with sand or lixiviated ashes.

I shall add also, that it will be advantageous to employ two kinds of sand in the formation of the bason of the cupell; one kind fine like that used by founders, and the other coarser and not earthy: the latter will form the first stratum, which, after being beat with rammers destined for that purpose, ought to be about three inches and a half in thickness. The fine sand, a little earthy, must then be applied over this first stratum to form a second, which is to be rammed like the former. Both these kinds of sand must be somewhat moistened before they are introduced into the furnace, in order that they may be better heaped up, and be consolidated by the rammers.

The sand of the lower stratum, being coarser than that of the upper, will absorb the moisture of the latter in proportion as it evaporates; and it will pass without any obstacle through the canals disposed for that purpose.

The lower stratum of sand may remain in its place when a new cupell is to be constructed with fine sand, and the part of the latter, which has not been impregnated with oxyd, must be mixed with new sand to form a cupell. Care must be taken in raising this sand not to touch the lower stratum; for the sand of the latter, which is coarse, must not be mixed with the other. This inconvenience may be avoided by beating over the bed of coarse sand a thin stratum of ashes, at which you must stop in removing the fine sand of the upper stratum.

It has been said that the founders' sand must be somewhat earthy, and that, if it is not, a little argil must be added to give it cohesion: but, as it is necessary that this

argil should be uniformly diffused through all the parts of the sand, it must be diluted in the water with which the sand is moistened, and the whole must be carefully mixed.

It may be objected, that as cupells of sand do not absorb so much litharge as those of ashes, more time will be required to terminate the operation of refining; since, in the new process, the oxyd, instead of being absorbed, ought to flow from the furnace. This circumstance needs excite no uneasiness; for the wind of the bellows, if well directed will make the litharge flow along the gutter more abundantly than if there had been an absorption.

I have seen refiners in Germany, who, in constructing their cupells of ashes, formed in the middle of it a small circular depression the diameter of which was proportioned to the quantity of the silver which they knew to be contained in the lead subjected to the operation. By this excellent disposition no grains of that valuable metal remain insulated from the cake; the whole runs into the central bason, and forms a cake perfectly round. I would recommend this practice.

I am certain that the cupells here proposed, if carefully and properly constructed, will be attended with complete success; will be free from the inconveniences of those of ashes, and at the same time will be economical. I am desirous, for the benefit of metallurgy, that the method here pointed out may be put in practice; it will prove that we ought not to be too tenacious in adhering servilely to ancient usages or to the common routine of workmen.—14 *Philos. Mag.* 210.

Acetite of Lead. There are two acetous salts of lead: one wherein the vinegar is saturated, which is Goulard's extract of saturn, the quack medicine (though a good one) commonly used to apply to inflammations, burns and

scalds, and bruises. It is this last only, which is the chemical test of the presence of mucilage and gum: whereon see Dr. Bostock's paper in 11 Nicholson's Journal, p. 75. This saturated salt of lead, Goulard's extract, or the aqua lythargyri acetati, contains lead 21, acetite acid 5, oxygen 2,1, water 71,9: whereas the sugar of lead or acetite of lead of commerce contains in 100 parts, lead 15,3, acetite acid 7,5, oxygen 1,5, water 75,7.

Take the corroded lead scraped off the blue lead in the manufacture of white lead: dissolve this in strong, clear, well-fined, colourless vinegar. If it be not so, it must be made so by distillation. A moderate heat will assist the solution; but if heat be applied, it should be in close vessels. The vessels should be of glass or earthen ware; (or perhaps tin might answer). The vinegar should not be quite saturated. The solution should slightly redden litmus paper. Draw off the solution quite clear. Crystallize by slow evaporation. If the crystals be not perfect, dissolve the crystallized mass over again in distilled vinegar, which I believe the Dutch always use.

I fancy the first washings of the white lead in the white lead manufactory, may be worth saving and evaporating, where the intent is to make sugar of lead.

This I believe to be the process: but I am not confident of the accuracy of my information. In my time it was not made in England: it was entirely imported from Holland. The calico printers used it in very large quanties to make printers mordant, the acetite of alumine. This is made by mixing from one part to one part and a half of sugar of lead in saturated solution, with a saturated solution of one part of ground alum. The alum must be previously tried to see whether it contain iron: if it do, it will turn the madder red of a chocolate hue.

I have already suggested, that the acetite of lime, made

by dissolving whiting or chalk in strong vinegar, well fined, may be substituted for sugar of lead.

Sugar of lead, is coming greatly into fashion in doses of from one to three grains, in cases of hemorrhage of almost every species.

It has been proposed to substitute the pyroligneous acid for vinegar, and it may be done; but whether it may be done as cheaply as by making vinegar out of cyder, or whiskey and sugar, I cannot say. The Messrs. Mollerats (Freres) at Paris, some years ago, presented a memoir to the institute, in which they announced the making of strong vinegar from the pyroligneous acid, or the acid distilled from wood. It had the pungent smell of radical vinegar: one pint would make a gallon of vinegar of ordinary strength, very clear, very pure, and very pleasant. I know not the process. Dr. Bollman has made it in small quantities perfectly well. I have made it, not quite free from empyreuma, in the making of carburetted hydrogen as a gas-light from wood, before my class. The acid liquor that comes over when the wood is distilled being percolated through charcoal, then saturated with chalk, again percolated, and the acetite of lime so produced distilled with sulphuric acid, will produce a pyroligneous acid, which however still retains more empyreuma, than can be borne to be used in cookery.

The empyreuma perhaps would be of no consequence in making a rough and impure sugar of lead for calico printers, any more than when it is used by them to make the pyrolignite of iron, for their blacks. But concerning all this I know little experimentally. It is a subject worth pursuing.

Patent Mineral Yellow. The fused muriat of lead, produced by decomposing common salt by means of litharge; triturating it in the form of a thin paste with

water for twelve or fourteen hours; washing away the soda; and drying and fusing the white muriat, I have already mentioned under the head of white lead a few pages back; I shall therefore say no more about it. Turner's patent was taken out February 26, 1780. It was set aside in 1787. See Turner v. Winter, 1 Durn. and East, 602.

But as the method of making it in this country, appears to me to be an improvement, I shall give it. I am obliged for the process to Dr. Hunter.

Take 66 lbs. litharge, and one bushel of salt: (by the way I would remark, that one bushel of Lake or Genesee salt, of Liverpool fine, and of Norwich fine, will weigh but 56 lbs.: a bushel of Liverpool salt, second fine, lightly put into the measure and not pressed down, will weigh 61 lbs.: a bushel of St. Ubes' salt in like manner, will weigh 76 lbs.: of Turk's island salt from 83 to 84 lbs.: All this I have tried myself, T. C.) Dissolve the salt in a pan. When dissolved, strain it and pour back the liquor into the pan: then add the litharge, keep a strong fire under the pan for three hours, until the mixture be perfectly white. The liquor then is caustic mineral alkali, which must be poured off and preserved. Then wash off the alkali that remains in the sediment by repeated waters, adding it to the liquor poured off. Take the sediment, which is a muriat of lead; dry it on chalk stones; when dry, put it in crucibles half filled, and melt the substance in an air furnace. The crucible should be covered, for any carbonaceous matter will reduce the muriat into metallic lead. It should remain in the furnace till cold, to preserve its crystallized form.

Sheet Lead Boxes. These are convenient in many respects for the keeping of substances, that require to be preserved from air and moisture. But as it does not seem

to me a business of much importance, I shall only refer to the method of making these boxes, in No. 2. of vol. 1. p. 133, for July, 1802, of the New Series of the Repertory of Arts.

Shot. Is made by melting lead with arsenic, and pouring it out of Troughs from a great height into a large vessel of water. The height is intended to give rotundity to the shot: the arsenic to make it more fusible, so that it shall preserve its rotundity arising from its liquid state until the moment when it is required to be condensed. Mr. Paul Beck's shot manufactory at Philadelphia, is, I believe, 175 or 180 feet high. The first fall for small shot is about 130 feet, the second fall or melting place, is about 170 feet high.

I give below the common English processes: but in my opinion the practice is, to melt the whole quantity of arsenic, with a small portion of the lead first: and then to add this strongly arseniated lead to the unalloyed lead, when the latter is melted. The arsenic, *should not be orpiment.* It should be white arsenic. It should be mixed with three or four times its bulk of charcoal, lamp-black, rosin, or some carbonaceous or inflammable substance, and being tightly inclosed in several folds of paper, should be thrust down with a stick to the bottom of the lead. The pan of melted lead, should be then covered, in order to aid the impregnation of the lead with the arsenic. The pan should be of thin cast or thick sheet iron; for the heat must not be too great. It is right, when the surface of the lead is irridescent.

As the general method of making shot is kept a secret, I give all the processes I have.

Patent Milled Shot, is thus made; sheets of lead, whose thickness corresponds with the size of the shot re-

quired, are cut into small pieces, or cubes, of the form of a die. A great quantity of these little cubes are put into a large hollow iron cylinder, which is mounted horizontally and turned by a winch; when by their friction against one another, and against the sides of the cylinder, they are rendered perfectly round and very smooth. The other patent-shot is cast in moulds, in the same way as bullets are.

Common Small Shot, or that used for fowling, should be well sized; for, should it be too great, then it flies thin and scatters too much; or if too small, then it has not weight and strength to penetrate far, and the bird is apt to fly away with it. In order, therefore, to have it suitable to the occasion, it not being always to be had in every place fit for the purpose, we shall set down the true method of making all sorts and sizes under the name of mould-shot, formerly made after the following process:

Take any quantity of lead you think fit, and melt it down in an iron vessel: and as it melts keep it stirring with an iron ladle, skimming off all impurities whatsoever that may arise at top; when it begins to look of a greenish colour, strew on it as much auripigmentum or yellow orpiment, finely powdered, as will lie on a shilling, to every twelve or fourteen pounds of lead; then stirring them together, the orpiment will flame. The ladle should have a notch on one side of the brim, for more easily pouring out the lead; the ladle must remain in the melted lead, that its heat may be the same with that of the lead, to prevent inconveniences which otherwise might happen by its being either too hot or too cold; then, to try your lead, drop a little of it into water, and if the drops prove round, then the lead is of a proper heat; if otherwise, and the shot have tails, then add more orpiment to increase the heat, till it is found sufficient.

Then take a plate of copper, about the size of a trencher, which must be made with a hollowness in the middle, about three inches compass, within which must be bored about 40 holes according to the size of the shot which you intend to cast: the hollow bottom should be thin; but the thicker the brim, the better it will retain the heat. Place this plate on a frame of iron, over a tube or vessel of water, about four inches from the water, and spread burning coals on the plate, to keep the lead melted upon it; then take some lead and pour it gently on the coals on the plate, and it will make its way through the holes into the water, and form itself into shot; do thus till all your lead is run through the holes of the plate, taking care, by keeping your coals alive, that the lead does not cool, and so stop up the holes.

While you are casting in this manner, another person with another ladle may catch some of the shot, placing the ladle four or five inches underneath the plate in the water, by which means you will see if they are defective, and rectify them. Your chief care is to keep the lead in a just degree of heat, that it shall be not so cold as to stop up the holes in your plate, nor so hot as to cause the shot to crack; to remedy the heat, you must refrain working till it is of a proper coolness; and to remedy the coolness of your lead and plate, you must blow your fire; observing, that the cooler your lead is, the larger will be your shot; as, the hotter it is, the smaller they will be.

After you have done casting, take them out of the water, and dry them over the fire with a gentle heat, stirring them continually that they do not melt; when dry, you are to separate the great shot from the small, by the help of a sieve made for that purpose, according to their several sizes. But those who would have very large shot, make the lead trickle with a stick out of the ladle into the water, without the plate. If it stops on the plate, and yet

the plate is not too cool, give but the plate a little knock, and it will run again ; care must be had that none of your implements are greasy, oily, or the like ; and when the shot, being separated, are found too large or too small for your purpose, or otherwise imperfect, they will serve again at the next operation.

Shot, tin-case, in artillery, is formed by putting a great quantity of small iron shot into a tin cylindrical box called a cannister, that just fits the bore of the gun. Leaden bullets are sometimes used in the same manner ; and it must be observed, that whatever number or sizes of the shots are used, they must weigh with their cases nearly as much as the shot of the piece. [*Greg. Encyclo.* 665.

Lead, how formed into shot. Lead is employed in considerable quantities in the casting of shot, for which a patent was granted in 1782, to Mr. William Watts, in consequence of his invention for granulating lead, solid throughout, without those imperfections which other kinds of shot usually present on their surface. The patentee directs 20 cwt. of soft pig-lead to be melted in an iron pot, round the edge of which, a peck of coal-ashes is to be strewed upon the surface of the metal, so as to leave the middle of the latter exposed. Forty pounds of arsenic are next to be added to the uncovered lead, and the pot closely shut ; the edges of the lid being carefully luted with mortar, clay, or other cement, in order to prevent the evaporation of the arsenic. A brisk fire is then kindled, so that the two substances may be properly incorporated ; when the metal ought to be skimmed and laded into moulds, that it may cool in the form of ingots or bars, which, when cold, are called *slag*, or poisoned metal— 20 cwt. of soft pig-lead, (according to the quantity of shot intended to be manufactured) are next to be melted in the manner above directed ; and, when it is completely lique-

fied, one of the ingots or bars of slag must be added: as soon as the whole is combined, a small quantity of the liquid metal is to be taken out with a ladle, and dropped from a height of about two feet into the water. If the shot be not perfectly round, it will be necessary to add more slag, till it drops in a globular form. The metal is next skimmed, and the scum poured into an iron or copper frame perforated with round holes, according to the size of the shot designed; the scum is then to be squeezed while soft, through the frame, into which the liquid should be poured, and dropped through the holes. For the smallest shot, the frame must be at least ten feet above the water, and for the largest, about 150 feet; the height being increased or diminished, in proportion to the size of the shot. [1 *Art. Man.*

Shot Manufactories have lately been established or revived, and appear to promise to supersede the importation of English shot. They are manufactured principally from Lead found in Louisiana, and shipped from New-Orleans.

Patent shot, as Dr. Black has informed us, are manufactured in England as follows:

A little orpiment or arsenic is added to the lead, which disposes it to run into spherical drops much more rapidly than it would do when pure. The melted lead is poured into a cylinder, whose circumference is pierced with holes. The lead streaming through the holes soon divides into drops, which fall into water, where they congeal. They are far from being all spherical, many being shaped like pears, and must be picked. This is done by a very ingenious contrivance. The whole is sifted on the upper end of a long, smooth, inclined plane, and the grains roll down to the lower end. But the pear-like shape of the bad grains makes them roll down irregularly, and they

waddle as it were, to a side; while the round ones run straight down. They are received into a sort of funnel, which extends from the one side of the inclined plane to the other, and is divided by several partitions, so that it is really the mouth of several funnels, which lead to different boxes. Those in the middle receive the round grains. [2 *Art. Man.*

The shot when made, is separated into sizes by means of sieves, whose wires are set according to the different sizes required. The shot is glazed by putting them into a barrel and turning it round, till by the friction and attrition they become perfectly round, smooth and shining.

I believe in this country, the proportion of arsenic is nearly as follows. About 7 lb. of arsenic is first added to about five hundred weight of the metal. Then of this mixture, so much is taken to add to the fresh lead, as will make the proportion of arsenic about 2 1-2 or 3 lbs. to the ton. Of this about one half a pound will evaporate. Compare this with the English patent proportions above given.

In the Louisiana country, shot manufactories are established, where the shot is made by letting the lead fall from the top to the bottom of the bank of the Mississippi, at low water: so that the enormous expence of such a building as that in Philadelphia, is saved. T. C.

To ascertain the quantity of whiting in white lead.

Take a specimen of flake white which is generally pure white lead, an ounce for instance: mix it with twice its bulk of lamp-black, or with oil, or with rosin: fuse it, and the instant it is fused, take it off the fire, let it cool and weigh it. You may fuse it in a small crucible or even in a tobacco-pipe, stopping the hole inside with a small piece of the tobacco-pipe. Then treat in like manner the lead you wish to try: The difference in weight

will be the adulteration. This process may be checked thus. Take the scoria of the last mentioned fusion; dissolve it in muriatic acid or nitric acid: filter it: precipitate it by carbonat of potash (a solution of pearl ash): wash and dry the precipitate, which will be a carbonat of lime, or whiting. The weight gives the quantity of whiting wherewith the lead was mixed.

Or, dissolve the lead you suspect in nitric acid; precipitate by well made, saturated, prussiat of potash, or prussiat of lime. The prussic acid will throw down the lead only. This may be washed, and melted with any reducing flux. If prussiat of potash be used, precipitate the remaining solution by carbonat of potash, which will throw down the carbonat of lime, which being washed, dried and weighed, will give the weight of the adulteration.

Or, dissolve the lead suspected in nitric acid: precipitate with a solution of sulphuret of lime. This will throw down only the lead.

Or, dissolve in nitric acid; and precipitate with chromat of pot-ash, which will not decompose nitrat of lime.

Chromat of Lead. This beautiful colour may be made thus.

In the vicinity of Baltimore and Philadelphia, the Granite and the Gneiss of the primitive strata, are succeeded by Steatite and Amphibole: these two last appear to be somewhat intermingled (but not in the same stone): to these as a stratum, succeeds the granular or crystallized primitive limestone, which, near Philadelphia, is the marble of White Marsh. Between the limestone and the steatite, but enveloped in steatite, in Chester county about twelve miles from Philadelphia, and at the Bare hills about nine miles from Baltimore, is found a chromated iron. When this pounded fine, and treated for an hour in a

strong red heat with three fourths of its weight of clean pure nitre, the nitric acid is decomposed, the chrome is acidified, and then combines with the alkaline base of the nitre, forming a chromat of potash. To obtain this pure, the solution must be repeatedly crystallized to get rid of a small portion of iron, which will gradually fall down in an oxyd; the other impurities, such as the earths that might have been taken up in small quantities, will also fall down. The solution after two or three crystallizations will then contain nothing but chromat of potash, together with a small quantity of nitric, or uncombined alkali; this can be ascertained by an intermixture of white with the yellow precipitate of lead; and can be obviated by a small quantity of nitric acid. When the chromat of potash is concentrated, and added to a solution of nitrat or even acetat of lead, (which need not be religiously saturated with metal) a yellow precipitate will fall down, which is the yellow chromat of lead. The chromat of potash will throw down nitrat of mercury a deep orange colour.

Naples Yellow. This ought to be a natural production found near Naples; a kind of lava, unchangeable by fire and by acids. The artificial kind is thus made. Take 12 ounces of pure white lead, and 2 ounces of washed calx of antimony; the common diaphoretic antimony of the shops; half an ounce of calcined Roman alum, which is generally free from any admixture of iron, and one ounce of sal ammoniac. Pound them well together, and put them in an earthen crucible with a cover. Keep them in a low red heat for three hours. If you want, the mixture more of a gold colour, add a quarter of an ounce more of antimony, and as much sal ammoniac. Do not let any iron touch this colour.

For patents relating to white lead see Repertory of Arts, Old Series, vol. 3. p. 225, vol. 5. p. 249, vol. 8. p. 378, vol. 11. p. 38. New Series, vol. 6. p. 169, vol. 7. p. 399. For the manufacture of sheet lead, see Repertory of Arts, New Series, vol. 1. p. 133. For refining lead, Ib. New Series, vol. 2. p. 72, vol. 4. p. 194. T. C.

MORTAR.

On the Cement used in building, called Mortar. (By the Editor.)

Having finished the article Bricks, I proceed to that of mortar.

Limestone, when subjected to chemical experiment, is found to contain from 43 to 44 per cent. of carbonic acid gas, formerly called fixed air. It contains also a small quantity of water. When pure limestone is burnt in a lime-kiln in the best manner, one ton, or twenty hundred weight of 112 lb. to the hundred weight, will yield, about 11 1-4 hundred weight of good lime. The loss is, partly water; but chiefly carbonic acid gas. (Watson.)

A bushel of chalk will weigh 86 1-2 lb. A bushel of lime made from that chalk weighed when warm from the kiln, 66 1-4 lb. which is greatly too much: for a ton of the same chalk when *well* burnt, produced but 11 cwt. 1 qr. 19 lb. of lime. If burnt in the best manner, it ought not to produce more than 11 cwt. of lime. Ib.

A hard limestone from Lancashire weighed 184 lb. to the bushel, up-heaped. At Clitheroe in Lancashire the limestone up-heaped, weighs 147 lb. to the bushel. If the produce be more than 11 hundred weight or thereabout from the ton, either the limestone is impure, or the

burning is deficient, in fuel or in time. The burning ought to continue in a strong red, approaching to a white heat for at least ten hours.

Lime exposed to the air for about twenty days will be reconverted into limestone, and become perfectly useless as a cement. Dr. Watson converted into lime 540 grains of statuary marble: the lime weighed 304 grains: from the 10th of February to the 4th of March, it had gained so much in weight, that it weighed 515 grains. Dr. Higgins exposed 2 lb. of well burnt, non-effervescent chalk lime, to the air for 22 days; at which time it weighed 3 lb. 2 ounces and 1 drachm and a half. The greatest proportion of this accession of weight, is gained in the first 4 or 5 days.

This encrease of weight is owing to 1st. carbonic acid gas imbibed from the atmosphere: 2d. in smaller proportion, to water imbibed from the atmosphere. These substances thus imbibed, reconvert the lime into limestone. So that mortar made from such lime, might as well be made from powdered limestone. It is no cement: it produces no cohesion.

The deeper and more circular, is the heap of lime, the better is the inner part protected from the bad effects of the atmosphere. The external surface is spoiled first. If the lime be slacked, and made into a paste with lime-water, (water wherein some lime has been previously slacked) and protected by boards, on all sides and on the top, it may be kept for a long time tolerably well. Or if slacked into powder immediately on being brought from the kiln, and made up into a compact heap.

If lime from the kiln effervesces, or gives out air (carbonic acid gas) on being dissolved in muriatic or nitric acid, it is ill-burnt in proportion exactly to the quantity of this air which it yields.

Lime ought to be brought from the kiln, in a cart covered with boards.

It ought not to be brought in rainy weather. I have twice or thrice seen carts set on fire by this means. It ought to be kept in a dry place, with the precautions before mentioned. The neat rule is, expose it to the air as little as possible.

When the limestone is so good, and the burning is so complete, that twenty parts of limestone is fairly burnt into eleven parts of lime, which it can be and ought to be—then will such lime, used as recently as possible, require seven parts of sand to one of lime, to make the best mortar. It will require less sand in proportion as it is badly burnt, or by negligent exposure reconverted into limestone.

Nothing is required, to make the best mortar for building, but good lime and good sand.

No sand is good that contains any clay. It should be washed out.

No sand is good, that is rounded by attrition.

The best sand is quartzose, having flat sides and angles.

The best mixture of such sand, is half somewhat coarse, half fine: not too fine, for ground or powdered quartz, or flint may do for stucco, but not for mortar: the flat sides and angles are destroyed by the pulverization.

The theory of mortar appears to me to be this. Water is added, to enable the lime to crystallize, and to attract carbonic acid from the atmosphere. This is done gradually. If left quietly and undisturbed, to regain this gas from the atmosphere, the mortar crystallizes into limestone, and unites by the attraction of crystallization to the sides of the quartzose sand, best calculated to afford the strongest union or adhesion. The attraction is threefold, 1st. that of crystallization: 2d. that of chemical or elective attraction in the moist way; and 3d. the com-

mon attraction of aggregation or cohesion. I conceive each of these to be distinct.

Hence it is essential to good mortar, 1st. that the lime be burnt so as to reduce twenty parts by weight to eleven parts. 2d. That it be used as quickly as possible. 3d. That if it cannot be used quickly, it should be packed up when slacked in the smallest possible compass, and covered from the contact of successive changes of air. 4th. That to fresh lime, seven parts of sand are not too much: lime half burnt will not cement more than three parts. Hence the threefold extravagance of not using lime in a proper state: the lime is wasted: the weight of carriage is increased by hauling limestone instead of lime: and more lime is required to the same quantity of sand.

Though not essential to good building, it is very nearly so, that the brick (always supposed to be well burnt) should be dipt in lime water the instant before it is laid. The dust on a dry brick effectually prevents the adhesion of the mortar; and the brick also absorbs so much of the moisture of the mortar, that enough is not left to enable it perfectly to crystallize. Immersing the brick in lime water, makes it also less liable to imbibe moisture. It forms an impregnation of limestone.

When the lime is good, no addition of skimmed milk, animal gelly, oil, or resinous substances, or any other, contributes to the goodness of the mortar: good lime, good sand, are the only requisites.

The putting beams and rafters, or any other method of shaking the wall, and greatly disturbing the crystallization of the mortar while damp, injures its power as a cement.

In countries where limestone and fuel are plenty, and labour cheap, the ancient method of building walls by *grouting*, may be eligible. It is this:

The foundation being dug out the required width in proportion to the thickness of the wall, a strong frame of boards was placed on each side. The space between the boards filled up with any kind of stone most convenient and at hand, thrown in promiscuously. The interstices of large stones, were roughly filled in with smaller ones. Mortar made from fresh burnt lime and fine sand, being made into a paste sufficiently thin to be poured, was poured in upon the loose stones, and thus filled up every crack and crevice. In a few hours, the boards were moved forward to form a caisson for another part of the wall, and the joints of the stones where the grouting had exuded, were trimmed off. Many of the strongest and most durable of the very old buildings in England, were manifestly so constructed.

Where work is intended to be solid and substantial, grouting at every course is indispensable. It is indispensable also in all arch work: in England it is never omitted in arches. It never ought to be omitted in such cases, or in cut groin-work.

Brickwork in cellar walls, or cellar arches, never dries if the mortar be not good, and used fresh, before it has become effete.

All these remarks are still more essential in the building of public works, as fortifications, than in private dwellings. By attending to these directions, a wall of equal thickness will have more than double the strength it usually has, built in a common way: and the mortar or cement, moreover, will harden incomparably sooner. Water used to make a paste of pounded limestone (common mortar) and sand, can only be gotten rid of, from the middle of a thick wall by the slow evaporation of many years: but if the lime be really lime, and well and recently burnt, all the water even of grouting, is rapidly consumed as water of crystallization.

For *Stucco*, bone ashes well burnt and sifted, in the proportion of from one half to one fourth of the lime, is an addition useful to prevent the cement from cracking, without impairing its other good qualities; and this whether for inside or outside work. For the latter the proportion ought not to be of bone ashes more than one fourth.

The method of making bone ashes is as follows: I take it from page 172 of Higgins on Cements.

"I will premise a sketch of the most profitable processes by which they are prepared, at a moderate price not much exceeding that of good stone lime.

The bones collected in great cities, are broken to small fragments in a mill, and boiled in water, in order to extricate and save the oil of them. They are then put into a large iron still, through an aperture which is stopped up closely after the charge is made. The still, which opens into an apparatus of refrigeratory vessels, is heated gradually to redness, until all the volatile alkali, commonly called spirit and salt of hartshorn, is expelled from them, together with empyreumatic oil, water, and certain elastic invisible fluids: the alkali, being the only valuable article amongst these, is retained and condensed in the refrigeratory tubes and vessels with all possible care, whilst the elastic fluids, lest they should burst the vessels, are suffered to escape in places distant from the fire or the flame of candles, because they are combustible, and if they catch fire whilst air remains in the condensing vessels, explode like gunpowder.

The bones thus heated without being exposed to the air, are charred to blackness, but still remain combustible. When they are required in this state, the iron still is kept closed until they cool, and then the blackest of them are ground to fine powder, which is used as a sub-

stitute for ivory black, which is prepared in the same way from ivory. The coarser powder of these, is what I understand by powder of charred bones. But when this is not the manufacturer's design, the door of the iron still is opened whilst it is hot, and the charred bones which flame and burn when they meet the air, are thrown into a kind of kiln, at the bottom of which the air can freely enter, and maintain the combustion, until the bones are burned to whiteness, for the greater part. The white fragments are picked, and rather bruised, than ground, to a gritty powder, by a millstone which rolls on them vertically over an inclined circular plane. This powder passed through a sieve is called bone-ashes, which are much used in metallurgy, and fitter for our purposes in incrustations, than the powder of burned bones ground as pigments are. The fragments which have not been thoroughly burned in the kiln, form a dark grey powder; and mixtures of the white and grey burned bones afford bone-ashes of the lighter grey colours.

The whole quantity of bone-ashes, which is to be used in the same incrustation, ought to be well mixed; for it is impossible to sort the well burned or the grey bones so accurately as to secure an unity of colour in the parcels of powder which are successively prepared, and a very small variation of colour will be seen in the incrustation."

Water Cement, is made on the continent by mixing with good mortar, the ochry earth Puzzuolana, or a similar earth called Traas or Terras in England, where it is imported from Holland. It is mixed accurately with the mortar in proportion of about one third or one fourth of the lime. It is obvious that if precautions are necessary in any case to secure good and perfect lime, they will be necessary in the case of water cement.

I believe that the same proportion of almost any oxyd of iron, or of manganese, or even of the common smithy-slack of a blacksmith's shop, well sifted, will answer the same purpose. So will Basalt, burnt and ground.

Loriot's patent for water cement, consists alone in the mixing of ground fresh burnt lime with common mortar, which is manifestly imperfect and unscientific; inasmuch as old effete mortar, can never be equal to fine quartzose sand.

Higgins's patent stucco, is fresh, well-burnt lime one part; sand half fine, and half rather coarser, well washed from dirt and clay, six or seven parts; I think six parts best. Bone-ashes ground tolerably fine, equal to one fourth of the lime. The water used must be lime water. For inside work the bone-ash may be in proportion of a third of the lime.

Johnson's patent stucco, was characterized merely by an admixture of blood with the water used to make up the cement.

I regard Higgins's as the best. I have seen them, all both fresh used, and many years afterward. T. C.

PERKIN'S IMPROVEMENT ON WATER MILLS.

WITH A PLATE.

THE subscriber has recently obtained a patent for an improvement in water-mills, which, from actual experience, has been found to be of great importance; it consists in the complete removal of all the inconveniences heretofore experienced from back water.

It is a well known fact, that in most situations it has been found necessary to place water-wheels from one to three feet higher than they would be, were it not requisite to avoid the back water, occasioned by the freshets and high tides. In nearly all cases

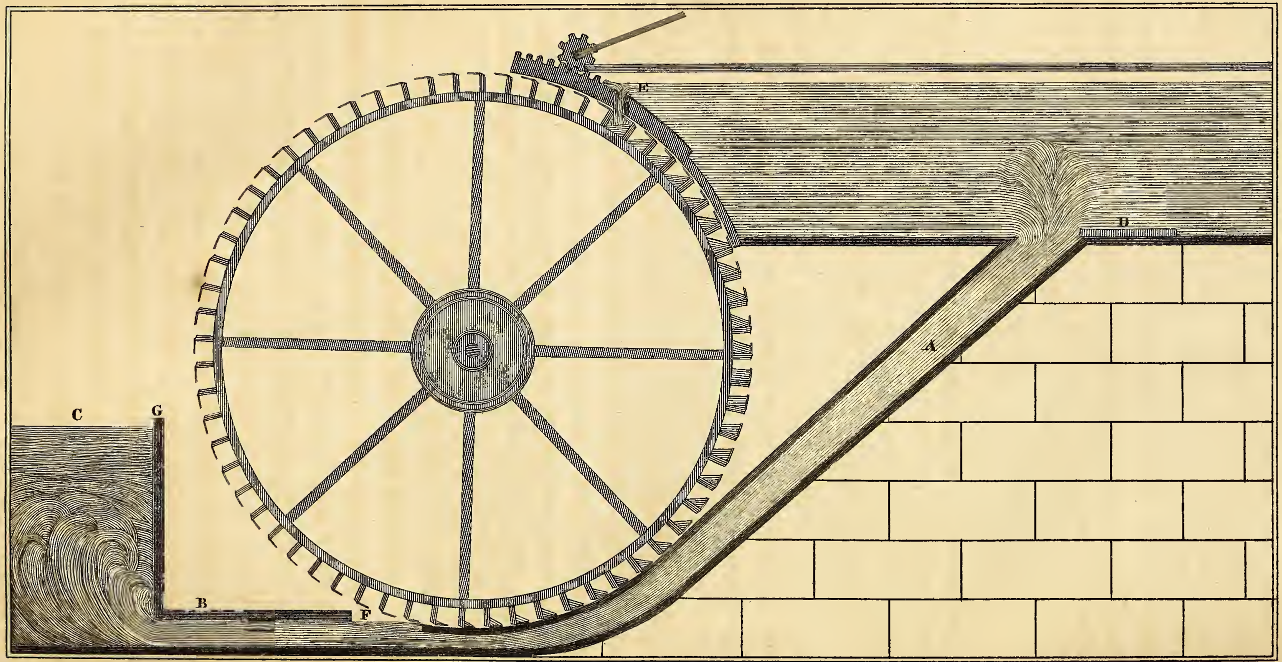
there is a serious loss of power, but more especially so where it consists of a few feet only. The patentee has satisfactorily proved, that with a head and fall of twelve feet, six feet of back water may be driven away, and with it, all the water which has been expended in moving the wheel: there is therefore, no exaggeration in declaring, that taking into the account the time that many mills are stopped by back water, and the permanent loss of power from the height at which the wheels are hung in order to avoid this difficulty; from one fifth to one third of the power is absolutely lost, an evil which is completely obviated by this invention.

All the time when the wheel is retarded by back water, a large quantity is constantly running to waste; this invention accomplishes its removal by the application of a portion of this superabundant water, which would otherwise run over the dam.

The above section will shew the operation of this principle in removing back water. The construction of the floom, and raceway, differs from the common form, by having a tight tube, A, running from the bottom of the floom, as at D, to or past the centre of the bottom of the wheel, and of about four times the size of one which would be necessary to turn the wheel. The size of the tube may vary according to the back water common to the mill. The lower end of the main tube, A, being in a direct line to that of the horizontal tube, B, will direct the water which rushes down the former through the latter, and at the same time overcome the pressure of the water and atmosphere at C, so that the atmosphere may act upon the back water which had collected round the bottom of the wheel, and force it through the tube, B, which being one third larger than tube A, will admit enough of the back water at the opening, F, to fill the tube B, and thereby in a few minutes, to entirely remove it from the bottom of the wheel; and the water which has been expended in moving the wheel, will join the current at F, and pass off through the tube B. The bulk-head, G, must rise above the extreme height of the back water, for as there is no other passage for the water to escape from the wheel, than through the tube B, there should be no other through which, in times of back water, it can pass to the wheel. When the freshet is over, and the water has found its lowest level, the horizontal gate, D, should be shut, and the water which carries the wheel will run off through the tube B.

This method of removing back water, will not apply to tide mills, except where there is a great surplus of water; in that case, by adopting this plan, the mill may be made to go sooner and later

Mr. Jacob Perkins's Improvement in Mills for the purpose of removing Back Water.



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than it otherwise would. Where the tide rises at the tail of a common mill, this principle may be applied to great advantage, as the wheel in many situations, may be set two or three feet lower than it commonly is, and by driving off the back water occasioned by the tide, the extra power which is gained by increasing the fall, will be much more than the loss of the water expended in drawing off the back water at high tide.

Communications upon the subject of this improvement will be gratefully received, and immediately noticed by the subscriber, the patentee, of Newburyport, Massachusetts, or by Dr. Thomas P. Jones, Philadelphia.

JACOB PERKINS.

STEAM ENGINE BOILER,

WITH A PLATE.

Sir—As steam engines are becoming much in use throughout the United States, every thing that will tend to their improvement in working, or in saving of fuel, ought to be made public. With this view I have taken the liberty of making a rough sketch of one of the boilers which has been in use upwards of ten years at the water works in Philadelphia, for your inspection. After giving every attention in ascertaining the effect of three different sorts of boilers in that work, for several years, I am fully persuaded, that it far exceeds any boiler now in use at the water works, or any other which has come under my notice, both in saving fuel and the ease with which the steam can be kept up. This boiler is, and always has been, defective, by its having a wooden case, which cannot be kept sufficiently tight; and, with this great defect, it does not burn so much fuel as the others with cast iron cases, which have the fire under their bottoms, with flues passing through and around them. The present drawing contemplates a cast iron case, which would be durable, and, no doubt, last fifty or sixty years, as it is not exposed to the heat of the fire. *However, an objection may be made to its expense*, I am well persuaded that if those who have engines built, knew the value of a boiler of this sort, 50 per cent. advance in the first cost would be no object to them, as they would save far more than the difference long before the boiler would be worn out.

With a view that the plan of this boiler should be submitted to the citizens of the United States who wish to embark in steam engine machinery, I hand it to you to decide whether it is worth a place in your work now publishing or not.

With great respect,

FREDERICK GRAFF,

Superintendant of the Philadelphia water works.

THOMAS COOPER, Esq.

The plan is drawn to a quarter of an inch to the foot.

The perpendicular heater A, may be raised in size and situation to suit the idea of the builder.

The dotted lines in plan B, represents the flues C, above the fire bed, and which pass out of the boiler into the stack, at the mouth of which the damper is fixed.

D, the fire grates.

E, the door way, which can be so arranged, if required, to consume the smoke by lowering the fire bars or grates.

F, the water line six inches above the flue.

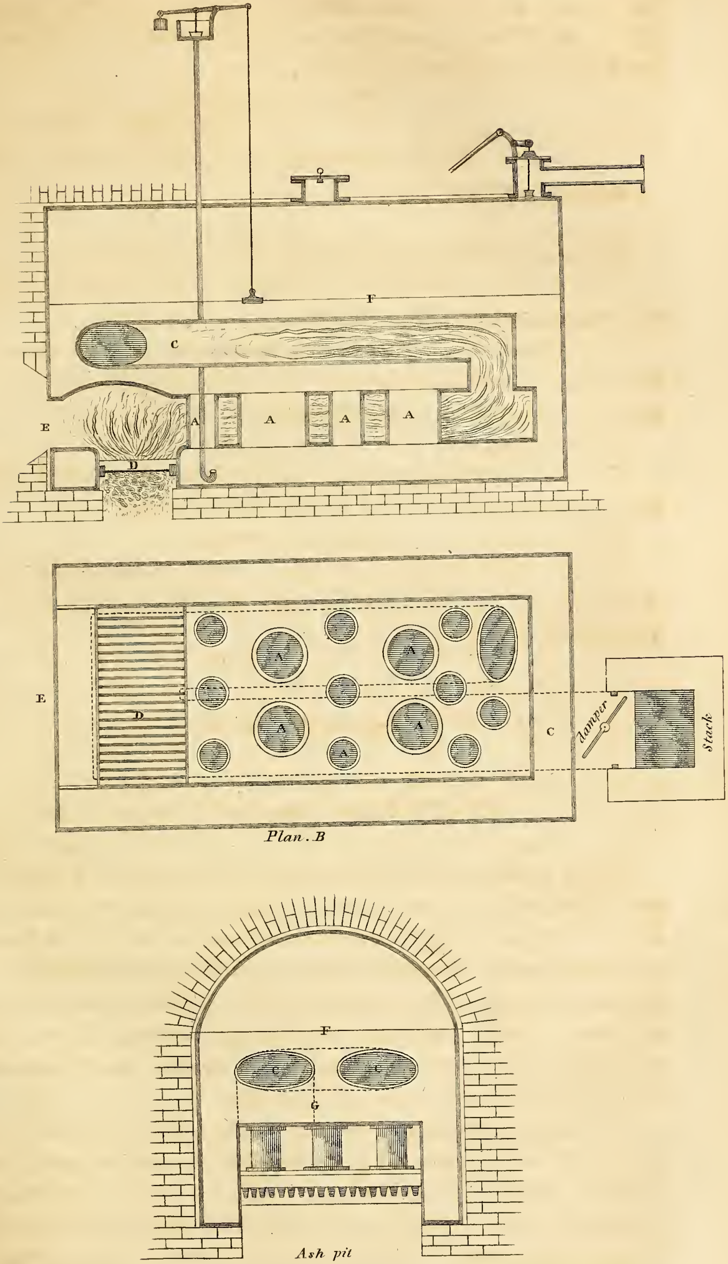
G, a section through the fire place, showing the front range of perpendicular heaters and the horizontal flues above, with coal grate and ash pit.

STATISTICS. By the editor.

Eight grain gallons of 268,8 cubic inches to the gallon make one Winchester bushel of grain; struck, that is even with the surface. The bushel ought to contain 2150,42 cubic inches: it ought to be 18,5 inches diameter throughout and eight inches deep. In England it is well settled as an indictable offence to buy or sell by any other bushel: I strongly incline to think, that it is indictable to buy or sell by any other bushel, here also: for I know of no other legal bushel.

Retailers in this country, generally sell every commodity whatever by the wine gallon of 231 cubic inches, without regard to the measure by which they purchase. Malt liquor is sold in England by the ale gallon of 282 cubic inches, being to the wine gallon, as one pound avoirdupois is to one pound troy. It is high time we

9 *Boiler at the water works, Philadelphia.*



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had a common standard of weight and measure in this country. The want of it is a sad reflection on our want of knowledge.

The peck loaf of England must weigh 17 lb. 6 oz.: for which about 14 lb. of flour is usually employed: the half peck weighs 8 lb. 11 oz.: the quartern loaf, 4 lb. 5 oz. 8 drs. Hence in the usual way of sale, 56 ounces of flour make 69 and a half ounces of bread; or 10 lb. of flour makes 12 1-2 lb. of bread.

The following facts were ascertained by direct experiment instituted for the purpose.

A Winchester bushel of good wheat weighing fifty-nine pounds, produced,

	lb.
Of the finest flour - -	28
Seconds - - - -	5 $\frac{5}{8}$
Fine middlings - - -	7
Coarse ditto - - -	3 $\frac{3}{8}$
Bran - - - -	15
The bushel - -	59

Also, 615 lb. of clean wheat was taken and ground: it produced 514 lb of flour, and 84 lb. of bran. The flour when baked produced 672 lb. of household bread, or at the rate of thirty per cent. beyond the weight of the flour. The salt, the yeast, and the wood employed to bake it, cost 5 shillings sterling: the workmanship 2s. 6d. I presume the bread was weighed while warm. This is at the rate of 13 lb. bread to 10 lb flour.

According to Lord Sheffield, the general calculation is, that a Winchester bushel of wheat weighing 60 lb. will produce 54 lb. of meal, 5 1-4 lb. of bran and three-fourths of a pound of water: and will make 68 lb. of bread: this is in the proportion of 13 1-3 lb. of bread for 10 lb. of flour. See vols. 26, 29, 35 of the Annals of Agriculture.

It appeared from the examination of the baker's about that period of scarcity in England, that American flour weight for weight produced rather more bread than the best English flour. Hence I conclude that 10 of American flour ought to make 13 of bread, if well managed.

The facts shew the great value in point of economy. 1st. In eating household bread, and 2d. In baking at home. The great art of baking, is in the laborious kneading of the dough. A small quantity of pearl-ash dissolved in the water, makes the bread somewhat lighter and assuredly wholesomer. All the bread used

in my family, is baked in a common ten-plate stove. I do not usually meet with better bread. I suspect the wheat of slaty upland, is heaviest and sweetest.

How much Land will supply a man with necessary Food.

I suppose a labouring man, sufficiently fed. Such a man will consume food of whatever kind it be, that will be equal in amount to one pound and a half of bread, one pound of meat, and half a pint of whiskey, per day. To which ought to be added, an allowance for fuel, pepper, salt, and a moderate proportion of vegetables. His dress will form another item: his habitation another.

One pound and a half of bread per day, will amount to 547 1-2 lb. of bread per year. At 13 lb. of bread to 10 lb. of flour, this will require 420 lb. of flour. If according to the experiment above related 615 pound of wheat will produce 514 lb. of flour, then 420 lb. of flour, will require 500 lb. of wheat. This at 60 pound to the bushel, will amount to eight bushels and one-third per annum. Allowing a little for indispensible loss and waste, this will be eight bushels and a half. In England the calculation is eight bushels annually, as the consumption of man, woman and child: and is near the truth. In this country we live more fully and less carefully.

I do not consider the average produce of an acre of wheat in the county of Cumberland, in Pennsylvania, which is a rich county of land, as more than 18 bushels per acre. The average produce of all England, is not less than 22 bushels of wheat per acre, when wheat is put in as a crop.

Since I have been at Carlisle, when flour has been at six dollars the barrel of 196 lb. net weight, wheat has been at $1 25 cents per bushel: butcher's meat six cents per pound: and whiskey by the quarter cask, at sixty cents per gallon.

	$	cents.
The grain required for one man per annum then will be 8 1-2 bushels at $ 1 25 cents	10	62 1-2
Meat, 365 lb. at 6 cents - - -	21	90
Whiskey 23 gallons, or allowing 2 gallons extra for harvest time 25 gallons	15	00
	47	52 1-2
Fuel, vegetables, pepper, salt, may fairly be considered as at least	7	47 1-2
	$ 55	00

It appears, that an acre of ground cultivated in wheat at 18 bushels per acre will yield 22 1-2 dollars in the market. But all the other articles are equally the produce of the soil. Hence if

one acre be required for 22 1-2 dollars worth of food, 55 dollars worth will require very nearly two acres and a half.

But where in good cultivation, a wheat crop cannot occur more than once in four years, interposing rye, oats, and clover, land that will produce eighteen bushels under usual culture, will not yield upon the average of a four year's crop more than the value of fourteen bushels. This will bring the quantity of land required in Cumberland county necessary to supply a labouring man there, with food and drink for a year, to three acres: the fractions in this calculation compensating for those in the preceding.

A man must have not only food to support him, but cloaths to cover him, and a dwelling to defend him from the inclemency of the seasons.

The dress of a labouring man cannot be estimated annually at less than 25 dollars in this part of the country: he must have a hat, a couple of cravats, a couple of shirts, a couple of pair of stockings, two pair of shoes, a coat, jacket, and pantaloons and two pocket handkerchiefs per annum.

He must have a habitation which will cost him not less than five dollars a year.

Hence if 55 dollars require three acres, 30 dollars will require upwards of one acre and a half. To maintain a labouring man then, free in Cumberland county, will require not less than four acres and a half of cleared ground producing an average crop worth at leat fourteen dollars in the market.—It is true that every man, woman and child, will not consume as much food as a labouring man, but the expences of the more expensive ranks of society, will more than compensate for this. If a labouring man spends necessarily at the *lowest* rate 85 dollars a year, the average of the community, can hardly be estimated at less than 110 or 112 dollars, (about 25*l.* sterling) which will demand eight acres per head producing as above to support each man, woman and child in the county.

In other parts of the United States, the cheapness of land-produce, and of course the cheapness of living, compensate each other: so that although the calculation in dollars will be affected, the calculation in land will not: hence eight acres of cleared land at least, are necessary to the maintenance of every human being in the United States upon the average. The present proportion therefore of about eight millions will require about sixty-four millions of cleared acres. If the weight of grain, flesh, and home-

made spirits exported were known, the actual amount of cleared land in the United States might be approximated: though part of this export has been considered under the article cloathing.

I am not at this moment aware of any material fallacy in the above calculations: when I am further instructed, I shall be glad to correct my suppositions.

Would it be too much to calculate the average value in the market, of each acre of cultivated land in the United States, at ten dollars? I think not. It follows then, that the yearly produce of our agriculture is worth six hundred and forty millions of dollars!

How the bloated panygerics on foreign trade, dwindle into comparative insignificance, when set in competition with this! Can we avoid recollecting the old fable of the Frog and the Ox, so emblematic of the subject?

If the potatoe and the turnip culture, with that of carrots and beets for cattle on sandy grounds, were introduced into the regular rotation of crops in this country as in England, I have no hesitation in expressing my belief, that the produce of at least ten millions of acres might be saved. The introduction of these crops, would also of necessity lead to a strict system of manure management, and the introduction of sheep to be folded for manure, and of tap rooted plants so proper in a warm climate, where moisture is not found near the surface.

Of the quantity of Land necessary to maintain a Working Horse.

Such a horse well but not extravagantly kept, will consume 12 pound of hay and 8 quarts of oats per day. If his labour be constant, not less than two ton of hay, and a hundred bushel of oats per annum will suffice. His manure will amply pay for straw for bedding. Manure when once laid upon land, is well worth a dollar a load of three horses, in that situation.

Under the average cultivation of America, this produce cannot be raised on less than from 7 to 8 acres of land. Shoeing and stabling will cost half an acre more. So that the expence of a working horse, is somewhat more than that of a human creature. It is not only so on a large scale, but every traveller knows it is so, on a small scale also.

When I travel in the back parts of Pennsylvania for instance, I allow my horse, as follows. Hay at night 25 cents: 16 quarts of oats a day, 50 cents: present to the hostler in the morning for cleaning my horse 12 1-2 cents: similar present at one stopping

place during the day six and a fourth cents: shoeing and casualties six and a fourth cents. Total expence of a horse per day, travelling from 35 to 45 miles, one dollar.

Allowance to myself. Breakfast 25 cents: cold meal, or check at stopping 12 1-2 cents: supper 25 cents: liquor during the day 25 cents, being half a pint of spirituous drink: bed 12 1-2 cents: total 100 cents. Such at least were the prices from 1800 to 1812 in this state.

Again: at the present day 1814, the expence of a horse at livery at Carlisle is 120 dollars: to which shoeing is to be added. The expences of travelling have encreased about one third within these two years: partly owing to a state of hostility, and partly to the almost sudden introduction of the paper of so many banks. So that still a horse and a man travel as to *necessaries* at about the same rate per diem.

Calculations of this kind, may be considered as useful exercises in political arithmetic. I have often wished to see a set of questions published as exercises, in general and local statistics: and the same with a view to render chemical calculations also familiar to a student. T. C.

When I had composed the above, I met with the following remarks of a similar nature from the Quarterly Review, No. 19, which gives a somewhat different aspect of the same subject.

" Leaving the further discussion of this topic to wiser heads than our own, we will now conclude our article with a few remarks on the general subject of subsistence and population.

" It has been generally supposed that about one quarter* of wheat, convertible into about 480lbs. of bread, is sufficient for the annual sustenance of an individual, on an average of all ages. If this were true, it would evidently be easy to ascertain, in any country of which the extent and population were accurately known, the average annual consumption and reproduction of food, to estimate the degree of comfort enjoyed by the inhabitants of such country, &c. But the number and variety of articles really employed for the purpose of food are so great, as to throw considerable doubts on the truth of this approximation, and it is perhaps impossible to furnish any which shall be free from considerable error; and it may be of some advantage to know the attempts which have been made elsewhere to solve this intricate problem, and we shall therefore here state the supposed proportion of ani-

* Eight bushels.

mal and vegetable food consumed in the French metropolis about the time of the revolution, as tolerably applicable to Great Britain.

" The data for such a calculation were very numerous in France, where every province has been accurately surveyed, the population of every district regularly registered, and the consumption of the towns minutely ascertained, by means of the entrance duty collected at the gates. The calculators, amongst whom were Lavoisier and La Grange, were men of undoubted science, and the result of their labours is, that the annual food of each inhabitant, as deduced from the population at Paris, amounts to 642 French pounds, (693 English) of which the vegetable food, including corn, potatoes, fruit, and garden esculents of all sorts, forms 435lbs. (469 English,) and the animal food, comprehending meat, fish, butter, eggs, cheese, &c. 207lbs. (224 English.) Now, if it be considered that the extent of pasture land in Great Britain is, at least, ten times as great as that of wheat land; that this pasture is, from the moisture of our climate, remarkably fertile, and that our insular situation must supply us with a much larger portion of fish than our French neighbours can easily attain, it may reasonably be presumed that the estimate which allots a quarter of wheat to the subsistence of each person, probably exaggerates, by about one third, the real consumption of grain in this country, and reduces, in the same degree, the amount of our whole annual sustenance.

" This proportion will, of course, vary in different districts, in different classes, and in different seasons; but, in general, there is reason to hope and believe that the ratio of the more nutritious to the less valuable species of food, is still increasing in the general consumption; that wheat continues to supplant the inferior sorts of grain, and that the comforts of the poor are more widely diffused. Of wheat, indeed, it is impossible to state with accuracy the annual produce, but the inference may be indirectly proved by the augmented consumption of the food afforded to us by our colonial agriculture. On an average of ten years, ending in 1801, the mean annual consumption of sugar was between 177 and 178 millions of pounds, which, divided by the amount of the population, (10,942,646) gives 16lbs. as the consumption of each individual in Great Britain. By a similar calculation on the next ten years, we find the consumption augmented to between 19 and 20lbs. for each person, the annual average being 240,800,000lbs. and the population 12,352,144. This is exclusive of the distille-

ries, and of the export to Ireland; and as it appears from experiment, that a hundred weight of sugar is equal, in point of nutriment, to a quarter of barley, or $\frac{8}{11}$ of a quarter of wheat, it seems to follow that the coarser kinds of grain, formerly in general use for the manufacture of bread, are daily giving way to more palatable articles of nutriment.

"With regard to animal food, the abundance of which has been at all times the peculiar boast of the British islands,* we know, by the direct evidence of the markets in the metropolis, that the quantity consumed is regularly increasing. This, indeed, as we

* The above is an extract from the Quarterly Review for October 1813, page 173. I do not comprehend how the authors or editors of that work can reconcile this passage with the following taken from page 266 of the same Review, for the July preceding (July 1813.)

"Food of every description has risen to an extravagant and unprecedented price. *Butcher's meat,* once in ordinary use, is now nearly beyond the reach of the great mass of the people: the labouring poor can scarcely hope to taste it: and as to *fish,* whether in the metropolis or in the great inland towns, that may be considered as a prohibited article even to the middling ranks of life."

Nor can I see how the extract in the text is to be forced into coalition with the following passage from the Edingburgh Review for the very same month.

Ed. Rev. October 1813. Guarinos on Poor Laws. The Reviewers say, page 197, "The precious metals have been depreciated throughout Europe, in consequence of the productiveness of the American mines during the last forty years: and in our own country (Great Britain), the rise of prices which this necessarily produced, has been aggravated by a depreciation of our currency, occasioned by the issue of paper not convertible into specie. What have been the consequences? The price of labour has not risen in proportion to the price of commodities. But the labourer has the difference made up to him in the shape of poor's rate. An unmarried man can still support himself by his nominal wages. But a married man who has two children to maintain, receives *as a matter of course,* assistance from his parish. A calculation is made of the price of wages and of the price of bread. So much bread is allowed him according to the number of his family. What his wages will not furnish, the parish provides. This beneficent system, as it has been called, turns out to be an engine in the hands of masters, to keep wages as low as will suffice for the maintenance of the labourer and his wife, with a provision in the shape of charity, for the support of his children." The rest of the passage is well worth citing, but it is too long.

If these passages be correct, what becomes of the great and increasing abundance and consumption of animal food, the peculiar boast of the British islands? One fourth of the population of that country cannot afford animal food above once a week, perhaps not once a month.

have seen, has been considered by many writers as a proof that our tillage has not improved in a degree at all proportionate to our pasture lands; but in truth it is the peculiar advantage of the modern husbandry, that the quantity of winter and summer provender for cattle, yielded by the plough, greatly exceeds the annual produce of grass and hay from the same quantity of land. If, however, this were not notoriously true, there can be no doubt that our fisheries might, for centuries to come, effectually supply the deficiencies of our agriculture. There are, indeed, no bounds to the possible accumulation of animal food; and its efficiency as a resource, in the failure of other nutriment, is only limited by its very perishable nature; an inconvenience, however, very easily remedied, so that we may perhaps be justified in expressing our belief, that if the proposed imposition of a duty on foreign grain were accompanied by a repeal of the tax on salt, the growing population of these islands might be supported, for centuries to come, in the enjoyment of increasing abundance."

TO THE EDITOR OF THE EMPORIUM.

Pittsburgh, January 8, 1814.

DEAR SIR,

I ENCLOSE a letter to the secretary of the United States, in which there may be found some hints of value, respecting the best method of making turnpike roads. If you are of that opinion, it is at your service; and, although written expressly for the secretary, who is absent, and whose leave I cannot therefore obtain, I believe that there can be no impropriety in giving it publicity. I have added an appendix explaining, and enlarging upon, some points which it was not necessary to enter into more particularly in my report.

I am, very respectfully, yours,

B. H. LATROBE.

Washington, October 31, 1813.

The Honorable Albert Gallatin,
Secretary of the Treasury of the U. S.

Sir,

AGREEABLY to my promise, I submit to you such remarks as occur to me on the perusal of the contracts of Messrs. Cochran, M'Kinley, and Randal, for making the United States' road from Cumberland towards Brownsville.

These contracts require the following description of a road.

1. The road is to be levelled from side to side to the width of thirty feet.

2. In the centre of these thirty feet, a pavement (as it is now the mode to call it) of twenty feet is to be laid in two strata: the first to consist of stones, which will pass through a ring 7 inches in diameter; the second of stones that will pass through a 3 inch ring. The pavement is to be 20 feet wide.

3. This pavement is to be laid 6 or 9 inches higher in the centre than on the edges, and the earth is to be raised up to the edges to prevent the stones from separating, or, in the technical phrase, it is to be shouldered.

4. There is to be a ditch on the upper side of the road and *contiguous to the pavement*, that is, upon the shoulder, or, at most, but a short distance from it.

I make no remark on the stipulated slopes, as some alteration has been admitted respecting them.

I will now, in the order in which I have set them down, give you my opinion on each of these points of construction.

1. As the general course of the road, excepting where it crosses a valley, is carried along the side of the mountains, the general section will appear as in the plate.

To the width of the road there can be no objection (A),* nor

2. To the width of the pavement. But to the construction in every other point, I shall take the liberty of offering such objections as both theory and experience have suggested, and as in a great many instances have been found solid in my own professional practice.

The idea of covering a road with stones of different sizes has, I believe, arisen originally in the expectation, that the soft clay or earth, which in most instances constitutes the natural soil, would be less easily penetrated by large, (especially by flat stones) laid

* See Appendix.

immediately upon it, than by smaller stones, such as necessarily form the surface of paved roads, for the sake of procuring a tolerably regular plane upon which to travel. This idea has afterwards been strengthened by the *economy* of the practice; the quantity of labour in breaking the stone being thereby diminished. But the expectations both of utility and economy are perfectly fallacious. In the first place, nothing is so certain, as that the large stones, let them be ever so carefully laid out at the bottom, will, in time, come up to the top, and that the small stones will all go to the bottom: and this effect will take place, sooner or later, exactly in the proportion in which the road is much, or little, used; and also in the proportion in which the size of the large stones exceeds that of the small ones. At first sight this may appear extraordinary, but the effect is natural and unavoidable. It occurs thus: A heavy load presses upon the new road, and of course moves all the stones down to the lowest (B), the small stones at the top descend into the interstices, which are thus opened. Every new pressure and motion continues this process. If the lower stratum consists of stones which are large and flat, they will get to the top sooner than round stones. A very familiar example will elucidate this process. Every housekeeper, in breaking a loaf of sugar, shakes the broken pieces in a box. Those that are too large, soon come to the top and are broken smaller. In shaking chesnuts in a basket, the largest will soon be at the top, and exactly on the same principle. If it were not invidious, I would point out several turnpike roads, or parts of turnpike roads, in Maryland and Pennsylvania, which prove the truth of this fact. As to economy, (C) the calculation is in the next place quite as bad a one. Such a road soon wants repair, and no repair, excepting that of breaking up the large stones as fast as they appear, is an adequate one. These large stones necessarily range themselves on each side of the ruts, until they work themselves loose, and then they lie in the horse path. Such a turnpike is soon fit only for slow heavy waggons, and for those it is a very bad one.

Now in the United States' road, the lower stratum of stones will consist, at an average, of pieces weighing each more than 12 times as much as each of the pieces that constitute the upper stratum: or in other words, that have more than 12 times the volume, or bulk. Of course, many years will not elapse, before this road will be exceedingly out of repair and covered with loose stones of an average diameter of seven inches. In a level country this would be a less evil than among the mountains. Every obstruction

of seven inches is a very serious additional difficulty in an ascent of four and a half degrees, to a loaded waggon the greatest radius of whose wheels is probably only 2 feet 9 inches.

3. In all roads whatever, it is an error to raise the centre above the shoulders of the road. If there are instances in which it is useful, I have not yet seen them. In a road merely thrown up out of the common soil, where the ground is very level lengthwise of the road, it is perhaps as well to raise the centre, because it will soon be beaten flat in dry weather by being chiefly used, and in wet weather, when the ruts or tracks are deep it is of no consequence, because the water cannot run off rapidly: but in all other cases, the convexity of the road is assuredly injurious.

In respect to their level, *lengthwise*, there can be only two kinds of roads. The first, such as are perfectly level, of which the instances are in the United States chiefly confined to sandy situations; the second, such as are inclined more or less to the horizon, and which in turnpike roads are permitted by law seldom to exceed in acclivity, an angle of four and a half degrees.

In the first kind of roads, that is in level roads if in any, it might be supposed that a convex surface would be useful, because the water falling upon the road, might be thereby carried into the ditches on each side of it. And this would happen without injury, if the surface were perfectly hard, and no ruts or tracks were cut into it by carriage wheels. But as the construction of the road, and the law regulating the passing of meeting carriages occasions the sides of a convex road to be used, more than the centre, the outer wheels will always bear the principal part of the load and of course cut the deepest track. If the road be perfectly horizontal, lengthwise, the water which falls on the road will run across the road into the outer ruts on each side, which are the lowest and the deepest, and stand in them until it finds vent on to the shoulder in a place accidentally lower. The whole water of the road on each side for some distance, being discharged through a few of these openings, the road will be gullied across its edges—as daily observations may shew. But if the road were perfectly flat, there would not be cut so easily a leading rut on the edge, and the water would run off as fast as it rose above the surface in innumerable places, and much less rapidly. It would therefore gully much less, and nothing is so certain, as that, of roads entirely unimproved, the flattest parts are certainly not the worst, because

they have the fewest gullies across them, unless the ground is naturally boggy.

It would be out of place here to give instances for the construction of roads in countries which are not sandy and yet perfectly level. I will only remark, that to raise the whole artificial part of the road a foot above the common level, to lay it flat across, and to effect a very small alternate rise and fall at short distances longitudinally would be a mode perfectly efficient—*as very ample experience has proved.* (D)

In roads however that have a natural inclination to the horizon, it is difficult to conceive, how the idea of convexity ever obtained admittance into practice. The makers of roads appear to have been more anxious to get rid of rainwater than on any other account. It is not pleasant to drive or ride through ponds or puddles in the public highway: but there need not be any fear, that they will abound or exist, if the surface of the road be well and equally laid, even if the road were quite flat, provided it were raised above the level of the land on each side. But in a road which has a longitudinal declivity the only danger is, that the water will run off too fast, and carry with it all the small particles of hard stone, which filling up the interstices of the larger pieces, fix them firmly in their places, and which convexing them in some degree diminish the friction of the wheels and preserve the road. There cannot possibly be any occasion to turn off these particles from the road altogether by a lateral (producing with the longitudinal declivity an oblique) current of water, and of course an oblique gully, even if the road could possibly be quite smooth and free from tracks and ruts. But as no road, and least of all, a convex road can be free from ruts, while narrow wheeled waggons are used, the convexity of the road becomes *useless* at least. For the water will run from the centre into the first rut that it finds and continue to follow it until it finds some vent sideways, accidental or artificial. Since then the convexity of the road cannot perform the service expected from it, on account of the longitudinal tracks, the actual evils it creates ought surely to be avoided. The principal of these is the unequal bearing of the load of carriages upon their wheels, thereby wearing the lower side of the road, and forcing—by the cutting of leading ruts;—all the waggons to follow the same track, in which track there will be always *chuck* holes* in the lower side, whenever a large stone happens to be

* In the middle states, *chuck holes,* are sudden and deep depressions in the rut, and are always found opposite to the root of a tree, an old stump, or a stone.

firmly fixed on the upper. It would be certainly a more rational construction to build up the shoulders of the road firmly with large stones rather higher than the road itself, and then to fill in perfectly level across with equal small stones. A road so constructed would retain its materials much better and longer than the other, especially if care were taken, to prevent as much as possible a very rapid discharge of the rain water from it.

4. Contiguous to the pavement there is to be a ditch. This ditch must be certainly intended to catch the water coming down from the sides of the mountain, on the slope of which the road is made. To get into the ditch then, the water must pass over 4 or 5 feet of unpaved soil, the pavement being directed to be made in the centre of the 30 feet, which are to be levelled. I have understood, that the road continues in many parts upon one uninterrupted ascent of a mile and upwards. If this inclination should be of four and a half degrees and *regular*, it may easily be imagined, what will be the effect of a current of water running over the soft soil for a mile, and not only increasing as it descends in velocity, but also in volume. The bottom of the ditch would soon assume the parabolic line which the slope of all mountains acquire from the wash of rain water; and the pavement would gradually be undermined and tumble into it. But I presume that there will be as usual, stops thrown up to guide the current across the road at proper distances, which, although not provided for in the contracts, is so far a practical remedy for the evil. But it must, even if this be done, be apprehended, that in time a gully will be formed on the upper side of the road; and this gully will take place on the soil between the ditch and the hill, making the whole of the upper unpaved level one irregular ditch.

Having thus objected to the whole construction of the road, you have a right to expect, that I should point out, what, in my opinion, it ought to be. This I will not hesitate to do, with the most perfect candour and freedom.

1. The road being cleared 30 feet in width, the upper boundary of the road should be so laid, as that the earth to be cut from the slope of the hill will be sufficient to raise the lower or forced side higher than the other; the surface inclining towards the hill about 1 foot six inches. The made ground will settle so as to become perhaps nearly level, but it should always be rather higher than the opposite side to prevent the water from running across the road. The cut on the hill side should be, in general, per-

pendicular, if the nature of the soil is tolerably tenacious. A perpendicular bank will stand much better, than any slope over which the rain water produces a current.

2. A drain ought then to be cut above the road upon the hill-side, about 12 feet from the edge of the bank, and about a foot deep, and the earth thrown towards the road, in order to catch the wash of the hill, and to prevent its ever reaching the road. Great judgment is required in cutting these drains. Whenever an opportunity offers, the drain should be turned down the hill from the road, so as to throw off the water among the trees and a new drain be commenced. (See plate.)

In many cases, this is impracticable; but wherever there are ravines in the slope of the hill, it may be done to advantage. All the wash of the slope will, however, at last require to be discharged across the road into the valley. Which should always be done by a small drain or tunnel, instead of an oblique draft, or sink across the road—than which nothing can be a greater nuisance, or a more contemptible means of economy, if indeed any thing is saved by the contrivance. The use of resting ascending teams is pleaded, —*valeat quantum valere potest.*

This upper drain on the slope of the hill is of the utmost importance, and cannot, without injury, be omitted. It is an object of very small expense, and being confined to no particular spot or form, may easily be repaired or shifted, should the remainder break over it.

No very accurate rule can be laid down of the manner of conducting it, as the numerous varieties of situation which occur, must suggest as many, both in the length and direction of these drains.

3. The pavement of the road of 20 feet in width, should then be laid entirely on the hill side of its width, measuring from the perpendicular bank, so that there will remain ten feet of unpaved road on the other side. This will afford an excellent summer road; whereas, if the road be paved in the middle, and only five feet remain unpaved, no carriage whatever can travel upon it. (E).

If the pavement be thus laid close up to the bank, no gully can be made between the road and the hill—for the water that falls between the guard ditch upon the slope, and the road, is of very little importance, and being discharged over the hard pavement, can do the road no injury.

Fig. 1.

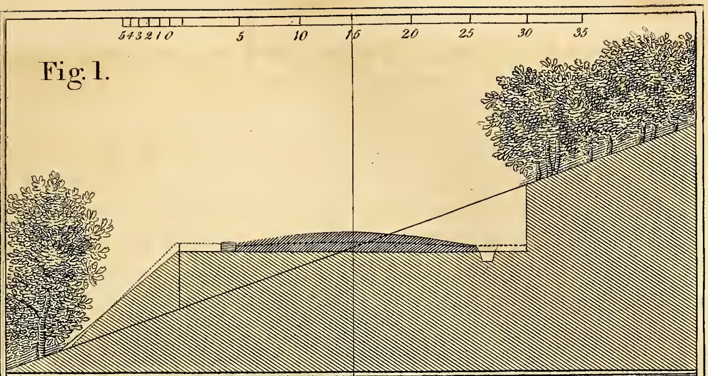


Fig. 2.

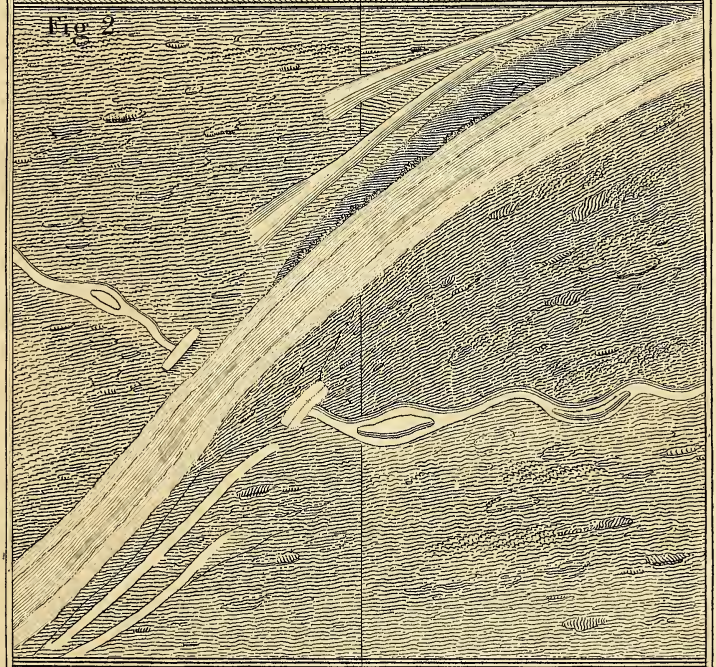
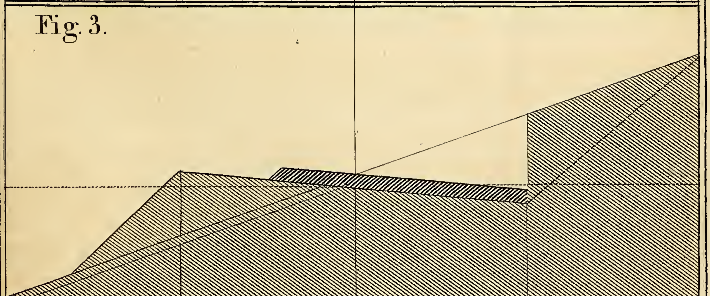


Fig. 3.



There is no doubt, but that in the course of years, earth from the perpendicular slopes will fall on to the road; but nothing is then more easily removed, and by degrees the bank will gain a slope at which it will stand, and be covered with vegetation. If the soil be naturally good, this will happen in three or four years.

4. The pavement should be laid perfectly level *across* the road, or rather, if at all, inclining a little towards the hill. All the stones should be broken to the same size. Stones that will pass through a 3 inch ring are of a very good size. But it were better that they should be even larger, than that larger stones should be laid first, and smaller stones upon them. That they should be all equal, is much more essential, than that they should either be very small or the stratum be very thick. A road of equal stones laid 8 inches thick, will last longer without requiring repair, than a road of two strata of different sizes of a foot thick. And a little reflection will convince any one, that it must be so. A shoulder of large stones would indeed be very useful; for it is important to prevent the road from spreading; but a shoulder of earth is probably sufficient, and admits of an easier passage from the paved to the unpaved road.

5. Culverts, *or if it must be so*, stops (these stops are admirable contrivances to make a ditch of the summer road) across the road, must be made to take off the rain water which falls upon the road, and also the wash of the hills below the guard drains. These must be placed where the judgment of the superintendant of the road may direct, according to circumstances. But, as I said before, drains or culverts should generally be used, and always to discharge the water of the guard drains—and where flat stones abound, their expense is very trifling.

6. The principal part of the U. States' road being carried upon the slopes of mountains, the section of the road I propose would be thus. (See plate.)

But where it is to be carried on an embankment over a valley, over ground which does not rise on one side above, and on the other fall below it, or over a ridge, then the pavement should be in the centre of the road, and the whole road be 40 feet wide at least. But in the case of a perfect level across the road, there must be a ditch on both sides at the extreme of the 30 feet, for the purpose of preventing water from running on to the road, and to carry off the drainings of the road itself. The paved part of the road may be laid six or eight inches higher than the sides, if the road be level longitudinally: otherwise it is not necessary.

I have now performed my promise, although in a manner much less full and systematical than I could have wished. I have only to add a request, that you will excuse the marks of haste which you may observe, and receive this letter as a proof of my anxiety to be useful to the public.

I am, very respectfully, yours,

B. H. LATROBE,

Surveyor of the public buildings of the U. States.

APPENDIX TO THE PRECEDING PAPER.

THE above report, being written for a specific purpose, does not contain all that information on the method of making public roads, which is so evidently wanted. I will therefore offer to you a few further remarks, by way of appendix to the report.

A.

A road of twenty feet wide, in the paved part, and having on each side five feet cleared and levelled, is for all the purpose of travelling sufficient. But such a road does not admit of travelling excepting on the paved part; because the wheels of all our carriages run 5 feet 3 inches nearly, distant from each other, in the rut. A summer road is therefore out of the question; and indeed, unless the summer road be wide enough to admit two carriages to pass each other, the ease of travelling upon it is dearly purchased by the necessity of turning off and on to it, even if it could possibly be an uniformly good road in good weather, and had all the advantages which your very judicious correspondent, O. E. in your 3d No. (October 1813) suggests.

The summer road is an object well worthy of attention in our country. If judiciously made, it will, in the middle states, and in common seasons, be a good road from May to the middle of July. The rains which fall in July and August would occasionally render it less eligible than the paved road; but from the end of August to the middle of November, often until Christmas, with the exception of a week or ten days about the equinox, it would again be the preferable road. During the month of January, the frost would generally give it solidity for a fortnight or three weeks; but from the first of February until some time in April, the breaking up of the frost, and the variable weather, would prevent its being much used. To make it useful, it is necessary, that it should not be the receptacle of the wash of the paved road, by being conti-

guous to and lower than the road—nor the depositary of the stones intended for repairs; that it should be protected by a ditch from the draining of the higher land; that it should be wide enough to admit the safe passage of two carriages, (not less than 15 feet); or that there should be a summer road on each side of the paved road of ten feet wide at the least, and that the law, which directs all carriages to turn to the right, should prevail in respect to these roads; or in other words, the carriages travelling upon them should be obliged to keep the paved road to their left hand. Of the necessity of each of these arrangements with respect to the summer road, every one who has travelled the Lancaster turnpike must be thoroughly convinced.

In mountainous districts, the maintenance of a good summer road will always be a matter of expense and difficulty; greater, probably, than would be rewarded by its advantages. And in the contracts for the great western road of the United States, therefore, it was right to omit any provision for such a road. But in the more level parts of our country, it is an object which would be well worthy of expense, and I think that by relieving the paved road from wear for 6 months nearly in the year, it would repay the money laid out in its maintenance. Its original construction is an object of small comparative expense.

B.

In passing along the Lancaster turnpike, I think in 1797, in a part then unfinished, I observed that a stratum of large flat stones was first laid upon the clay, and smaller stones broken over them. I stopped and stated my opinion to a person who appeared to superintend the work, on this injudicious mode of making the road; using all the arguments that occurred to me to convince him of the correctness of my remarks. He did not know me or my profession, and heard me with great civility; but I did not succeed in convincing him. In 1801, I passed over the same ground, and found the same person superintending a gang of men who were breaking up the large flat stones which then had arrived at the surface. There are many parts of the Lancaster road that now bear witness against this injurious practice; but the Reistertown road, near Baltimore, two or three years ago, afforded the strongest proof against the method of making roads by beginning with a stratum of large stones, that I have observed; for it was hardly passable for horses or light carriages, on account of innumerable loose stones lying and rolling in the horse path. The mode often adopted in covering turnpike roads is not very judicious, namely, to lay the stones down in

the road as they come from the quarry, and breaking them afterwards upon the road itself. It is no doubt the easiest method, and can be afforded at a less expense. But on the other hand it is open to great deception, and a very active overseer may be persuaded by appearances that the size of the stones is uniform, while the small ones cover large unbroken fragments. If the stones are broken up at the side of the road, and shovelled on from the heap, no such deception can take place.

C.

There is no word so little understood, or so much abused as the word *economy*. In nine cases out of ten in which it is attempted to be practised, its true meaning—the meaning proved correct by the result—is *the waste of ignorance or of inexperience*. The proverb, "Nothing is cheap that is useless," is like most other proverbs, fraught with an important lesson.

Nothing, in fact, is so cheap as the best workmanship employed on the best materials. Labour is productive in proportion as it is cheerfully performed; and no labour is cheerfully and well performed that is inadequately paid. Materials are cheap, in proportion as they are durable, and as the labour employed upon them is employed in sufficient quantity and with judgment. The bad condition and the unproductiveness of the stockholders of many of our turnpike roads, is to be attributed to the *hard* bargains, that is, the *cheap* bargains under which they were originally made, and the *cheap* materials of which they consist.

When however an important communication is for the first time to be opened, and when after every exertion that patriotism, and local, and personal interest combined, can make, a fund only adequate to make an indifferent road, can be raised—I then agree, that at all events the work should be *some how* performed, or, as our road-makers say, "*any how*." Such a road will always, before it becomes a good road, cost more in money, than a road well and permanently made at first, and undertaken, not by the lowest bidder, but by men who have honest principles and regard their engagements and their character, more than the amount of the profit they may make. Such men I have employed, and they are not difficult to be found. But it is hardly possible that a good road can cost too much, if the benefit to the community, and not to the stockholders is considered.

D.

The first turnpike roads made in the county of Essex, in England, over the perfectly level part of the county, and I believe all

the level turnpike roads, in level countries, which were constructed in the early period of this improvement of the public highways, were made on this principle, namely, of an alternate artificial ascent and descent.

My memory however furnishes me only with perfect knowledge of the fact; and I regret that I cannot point out the source of information from which I derived it. I recollect however passing over such a road in the hundreds of Essex, during some part of my residence of about ten years in England (about 20 years ago) and I also recollect having assigned, as reasons why the method was discontinued, that it was much more expensive than to *barrel* the roads (to give them a convex surface) and that the lowest parts were apt to be overflown. These are good reasons, although the discarded method is certainly preferable to that which succeeded it. The overflowing of the lower parts or kennels would be avoided by culverts or drains across the road. I know in our country no extensive levels, in which the soil is clay, and of course in which the roads are apt to be miry excepting the levels in the county of Fauquier, in Virginia, abounding in copper ore, and in which are the sources of the Occoquan. In Jersey, Delaware, and Maryland there are level and extensive clayey swamps, but all these may be drained, by carrying the drains to a sufficient distance. Having had occasion in the Peninsula between the Delaware and Chesapeake to run many miles of level through such flats, I have found them all to descend 6 inches in a mile to the S. E. In such situations, the whole road to the width of two rods (33°) should be raised above the level by the contents of deep and wide ditches on each side, before the hard material is carried on them.—And in my opinion they should be made perfectly flat, if not concave with occasional ditches and culverts or bridges across them. To make good roads over a rolling country, little art, but much labour, is required. The most difficult task, and that requiring the most art, is to make a good road over a level clay country.

In the level country between Retford and Gainsborough, in England, and throughout the clay flats of the counties of Nottingham and Lincoln, a sort of horse path exists, the continuation of which is ascribed to the Romans, and which is certainly not of very modern date. These paths are ditches, the bottoms of which are filled with sea-beach pebbles, (shingle.)

In several visits to that part of England I never saw them free from water; and have rode in them many miles, always wet above the horses fet-locks. They are to this day an excellent horse

path in the most miry country in the world.—I was informed that they had never, within the memory of man, been replenished with fresh pebbles. The proposition may seem strange, and will be no doubt ridiculed, but,—if travelling in water were not disagreeable,—I cannot help thinking that over a flat wet country such a ditch road 20 feet broad, filled with gravel or pebbles, or broken stones a foot deep in the bottom and having not more than six inches of water upon it, would be the best possible road that could be made. One cause of destruction would be avoided, the washing away of the hard particles separated by attrition; they would always remain and fill the interstices so as probably in time to convert the road into a sort of rock.—Nor would the frost, another powerful destroyer of roads affect it.—But it is useless to discuss a method which will never be used, and for which fortunately we have no frequent occasion.

Mr. Wilkes, an opulent banker in London, who possessed large estates in the county of Derby in England—and a spirit of enterprize combined with uncommon force of intellect, engaged largely in the making of turnpike roads in that county, and in conversations with him on that subject, I have received more information than from any other source whatever.

His roads were the best in England. On to some of them he had led a running stream of water; all that I saw were somewhat concave instead of convex. But least I should misstate any thing respecting them, for want of correct recollection, I will content myself with this notice of his operations, in order that you or some of your correspondents may be led to enquire whether or not something has been published by himself, on this subject. I have a faint idea that I have seen a description of the principles and method, by which he constructed his roads, in print.

E.

These oblique gutters are defended, as stopping places for carriages.—It is indeed, in common humanity, proper to stop in the gutter, after the horses have exhausted themselves by dragging a waggon or carriage over the ridge. But if the waggoner would carry along with him a block of wood with a handle, by way of a *scotch*, (catch) to his wheel he could stop where he pleased. The roller used in England would answer the same purpose, but although it effectually prevents the injury which might occur by the waggon's running back unexpectedly, it is not otherwise a better, nor a more convenient contrivance than the block.

Should the papers I now send, be honoured with a place in the Emporium, I will endeavour to collect all the information on pub-

lic roads, which my professional experience, or the books which I possess, or to which I can gain access may furnish and transmit it to you. Much is also to be said on the subject of wheel carriages, and the hint you have thrown out respecting the employment of small carriages in greater number, instead of heavy waggons, is well worthy of investigation.

B. H. LATROBE.

Pittsburg, Feb. 10, 1814.

I need hardly say, that I shall be greatly obliged by Mr. Latrobe's future communications on this important subject, so little understood upon principle, in the United States. My own collections on the subject of roads and one horse carts in particular, I will endeavour to introduce (if I can) in the next number: persuaded that though this be not a popular subject, it is a subject of great moment.

T. C.

ABSORPTION OF DELIQUESCENT SALTS.

Table of Efflorescent and Deliquescent Salts. By M. CADET. 26 *Till. Mag.* 242.

	Efflorescent Salts. 288 grains.		
Sulph. Soda	in 61	days lost of water -	203 grains.
Phosph. Soda	39	- - -	91
Carbon. Soda	51	- - - -	86
	Deliquescent Salts 288 grains absorbed		
Nitrat Soda	137	days - - -	257 grains.
Lime	147	- - - -	448
Magnesia	73	- - - -	207
Alumine	147	- - - -	300
Copper	128	- - - -	397
Zinc	124	- - - -	495
Antimony	124	- - - -	388
Manganese	89	- - - -	527
Muriat Lime	124	- - - -	684
Magnesia	139	- - - -	441
Alumine	149	- - - -	342
Copper	119	- - - -	148
Zinc	76	- - - -	294

Bismuth	114	-	-	-	-	174
Antimony	124	-	-	-	-	388
Manganese	105	-	-	-	-	629
Acetite Potash	146	-	-	-	-	700
Alumine	104	-	-	-	-	202
Acid sulph. alum.	121	-	-	-	-	202
Phosph. Lime	93	-	-	-	-	155

MANUFACTURES.

A Letter to a friend of the Editor, on Manufactures.

Sir—As I believe to promote the internal improvement, domestic trade, and industry of this country, is amongst the greatest services that can be rendered its society, you will not be surprised at my solicitude to engage your powers and influence in favor of a policy, in my opinion so perfectly adapted to preserve the government from the conflicts with, and influence of foreign nations; inseparable from a dependence on them for what is naturally, or has by habit become necessary to our citizens.

It has already been noticed, that Britain by the application to the affairs of society, of the powers of gravity, expansion, the various modifications of the mechanical principles, chemistry, all the arts and sciences, in short bringing to the service of her manufacturers, fire, air, earth and water, gives to each of them the power of producing sufficient to exchange for the labour of many agriculturalists, or persons employed in occupations that can only be performed by mere human labour. Let us endeavour to explain this imperfect subject and form some computation of what she gains in money, and then estimate from this, the number of human beings it would require to produce by their labour such an amount.

It is proper to premise, that the sums are stated on conjecture; but the principle is correct; and this paper is only intended to set you at work. The true data can be found in public documents, and British works on political economy, while much assistance may be had from Cooper, Fulton, T. Cox, Bolman, &c.

In the last published number of the Emporium, I think Cooper states the saving to the British from using Watt and Bolton's

steam engine, at 75,000*l.* a day, or in round numbers, at twenty-five millions per annum: so, heading the account with this,

1st. Annual saving by Watt and Bolton's steam engine at - - - - - 25,000,000*l.*

2d. Arkwright's spinning in all its varieties - 40,000,000*l.*

3d. Bridgewater's canal system including rail ways - - - - - - 7,000,000*l.*

4th. Threshing mill equal to 150 days labour at 2s. 6d. on 100 acres farmed after the stile of the Lothians near Edinburgh, and renting at 3 or 400*l.* per annum.

This last item I cannot fill up for want of documents to shew the extent of cultivated land in Britain, and the use of threshing machines thereon. But the saving from this, and the improvement of ploughs is very great; and enables the government of that country to tax all the land 15 per cent. per annum on its real rental. There may be other grand items that should be added to this account, and may possibly be suggested by the persons mentioned. To detail all the minor improvements that have been made, by employing the Tilt hammer, Roller, Screw, &c. in doing what other countries perform by the hammer, and manual labor, weaving by water, and having excellent roads, &c. &c. is not necessary here to state, and would require knowledge I do not possess; so these shall be thrown in, to keep the grand account entire.

Taking the total amount of saving by these four grand improvements at 75,000,000*l.* sterling per annum—and three shillings and four pence to be equal to one day's wages of a manufacturing workman, who for Sundays, holidays, and sickness, loses only 65 days in the year, (making 50*l.* sterling a year)—it equals the wages of 1,500,000 men.* This prodigious saving of human labour by manufactures and machinery, is the principal source which furnishes the means by which Britain supports her expensive government, her army, navy, clergy, nobility, revenue officers, subsidies, &c. which enables her to make roads, canals, &c. This gives her the command of 1,500,000 surplus men upon an equal population, whenever they are wanted for national purposes. Part of this she will lose by other countries adopting the same system, and working in the same manner for themselves or their neighbours: her statesmen are sensible of this, and do all they can to prevent it.

* The manuscript has it 750,000 men. T. C.

Now this addition of men whose work is performed by machinery, requires neither food, clothing, or lodging; the produce is clear gain, and adds more to the resources of a country like Britain where collecting taxes is so well understood, than the addition of German, Russian, or French territory, on which there existed thrice the number of agricultural inhabitants.

The success of manufactures depends on a decided national approbation and support; it is to manufactures we must look for the improvement of the country, by introducing good roads, canals, and rail ways. These in their turn will raise the value of land, and enrich and make comfortable the farmer; for generally, though our farmers are wealthy, they experience the plagues of poverty from not being able with ease to convert their abundance into the common medium of commerce, owing to the market being so far from them.

You must be very sensible such a system of home manufacture must have great influence in keeping America out of European squabbles: this is very important; and considering three fifths at least of the shipping merchants for the last nineteen years of my own experience, have either broken during their lives, or died insolvent, it furnishes room for reflection and inquiry a little farther into the mercantile system, before we assign to it all the good consequences which its friends are willing to suppose.

I would not from what has been said, have you conclude my opinions are hostile to commerce; on the contrary, I consider it essential to civil society: but its brilliant and striking character has a tendency to mislead our judgment and induce us to consider it almost exclusively as the source of productive wealth; which is not the fact; its foundation is on wealth already produced; but though it is an effect growing out of agriculture and labour, I acknowledge that in its turn it becomes a cause and assists the parents who give it birth. The brilliancy of foreign, is greater than domestic commerce, but in my opinion far less important.—Of this truth Britain is every day becoming more sensible; and her writers on political economy now acknowledge, that her domestic is at least six times her foreign commerce.

Would it be advisable for the president to recommend the consideration of this subject to Congress? Would it be of advantage to the nation to have a department under a minister or secretary of domestic affairs? The time is coming, when the nature and extent of our concerns will require a separation of the foreign and

domestic offices. It seems to me that order and expedition cannot be preserved without something of the kind, but perhaps we are not yet ripe for it. However, under these impressions I submit to your consideration the following remarks. Your's, &c.

J. R.

May 22, 1814.

ON MANUFACTURES.

Sir—I find it much more difficult to express on paper, in any thing like methodical order, ideas on manufactures, commerce, and political economy, than to talk about them; but it is pretty evident, and of course easily said, that the country that has its productive powers of *labour* and *capital*, duly apportioned into the three grand divisions of social employment, agriculture, manufactures, and commerce, will be the most independent of foreign nations; and its citizens will, in the most perfect manner, not rival, but support each other. On the contrary, a country all agricultural or commercial, while dependent on foreign nations for necessaries and comforts, has all its citizens rivals to each other. Farmers have little occasion to buy wheat and potatoes from each other; but the weaver, spinner, and smith, must purchase these articles; and their labour produces shovels, yarn, and cloth, with which they directly pay the farmer for his grain, beef, cotton, &c. or have the operation done through the merchant, as the common agent or factor.

As the United States, heretofore, have been occupied chiefly with agriculture and commerce, the country has been too dependent on foreign nations, and the people rivals to each other. The consequences of which have been very considerable. The interior is drained of its *increase*, to pay for foreign *necessaries*; the product of the farmer sells at a price reduced, in proportion to the expense of conveying it to the consumer; which on heavy or bulkly articles, such as flour and cotton, must be very great, when the producing places are at Boston, Pittsburgh, or Augusta, and the consuming places Paisley, Birmingham, or Madrid. The commercial class is too numerous; and their rivalship unduly raises the price of domestic articles at home, and lowers them abroad; the consequence of which is, that three fifths of the merchants on an average during the presidencies of Messrs. Washington, Adams, Jefferson, and Madison, have, either in the course of their

lives, or at death, been insolvent. The introduction of manufactures greatly alters this state of things, by affording employment for all kinds of genius, and any amount of capital; draws the superabundance of men and money employed in commerce, into manufactures; and bringing the consumer into the farmer's neighbourhood, can afford to pay him a higher price than he has heretofore received from the merchant; and at the same time, the consumer buys every thing at a price much below what it would have cost, had he resided in Manchester or Glasgow; in short, between them they save all the costs and charges incident to land and water transportation, agencies, commission, insurance, custom-house fees, and the whole list of direct and indirect foreign taxation; it is introducing into society the labour-saving principles, now well understood in manufactories. It would be unnecessary employment to enquire into the pro's and con's on the policy of manufacturing, urged twenty or thirty years ago. The astonishing improvement of arts and sciences has settled the question.

The propriety of manufacturing, might be questioned when the whole power of one individual was employed in making a single thread; when human beings carried on their backs, coals and minerals from the bottom of mines. A whole day was required by one man to make 10 or 12lbs. of nails. But every thing is changed. Now, all the powers of gravity and expansion, the elements of fire, air, water, &c. &c. are placed under the controul of man, and rendered equally subservient to his objects, whether delicately minute, or ponderous and bulky. A fibre of cotton or a bar of copper, are managed with equal facility, and the ends in view attained with the same accuracy. Capital employed in forming a dam, race, and saw mill, places a little ripple or a great stream, under the command of a few men, and makes it perform the labour of hundreds, at no expense of food, lodging or raiment. The same observation applies to the steam, and all other engines; so that manufactures are to nations, equivalent to encreasing their population. On reflecting upon these great improvements, the mind is struck with surprize, that no discoveries have been made to abridge the manual labour of husbandry. After the threshing-mill and cradle scythe, there is nothing of any consequence; nor from the nature of agricultural operation, is there a prospect of much alteration; and it is very probable that the United States, in exchanging her agricultural products with some of the European nations for their goods manufactured by the agency of machinery, give the labour of four farmers for one manufacturer.

Amongst the consequences resulting from this accession of manufacturing and mechanical power, is the ability accruing to these nations, of maintaining great armies and navies; too often employed to annoy the very persons who buy their wares.

It must be evident, that to bring into the service of man the mighty agents alluded to, and set them at work in preparing his food, cloathing, necessaries and luxuries, by habit become necessary; much capital, [accumulated labour, or in other words the product of labour not consumed,] must be invested in machinery and apparatus, which require time and labour to set up. Whereas all that a woman wants to enable her to spin one thread, is a wheel and reel, which can be procured for four dollars; and this is ten times the sum necessary to fit her up with a distaff; a business like this, may be begun and laid aside, on the exigencies of a week. Not so the other. Before a thread can be made, many thousand dollars must be expended on the mill and apparatus. A nation, to avail herself of the benefits growing out of the great improvements that have been introduced into the arts and sciences, must cherish the infant efforts of her citizens by *judicious* and *stable* laws, and inspire them with confidence to embark their property and time in those undertakings. A manufacturer and his capital have a fixed character, they cannot be changed like the merchant. Under these circumstances, no nation will progress, except her legislature contributes protection; and the farther other countries have advanced before she begins, so much stronger is the protection required. The United States possessing vast resources in the vigour and activity of her people, extent and quality of soil, uniformity of government and language, mines, forests, &c. &c., I once thought that a fixed duty of 35 per cent., would be sufficient to cherish those manufactures essential to her independence and wealth, but on more maturely weighing the subject, I think the import should be raised to fifty; that in two years from the termination of the present war, 5 per cent. should be taken off the import, and at the end of three years another 5 per cent., and at the end of four years, a farther reduction of 5 per cent. and the remaining 35 per cent. to be considered perpetual. This gradual way of lowering the duties, would be favourable to the revenue, the manufacturers and holders of foreign goods. A rapid reduction will be most mischievous to both the latter, and this cautious way of proceeding, would afford time to apply any special remedies that particular cases might require. It will soon be found that many particulars can maintain their ground advantageously, at much lower protecting

duties than 35 per cent.; indeed, there is no doubt that after a home manufacture is under way, and has for some time got possession of the market, it can combat the foreign one with greater effect at a duty of 10, 5 or no per cent. than it did in infancy at fifty.*

Compared with the duties of importation imposed by foreign nations, 50 per cent. is low. I think the duty on a yard of woollen goods imported into Britain is $ 6 22 cents, be its quality what it may; even the raw materials of cotton, turpentine, logs of wood, &c. exceed in France and Britain, what is here charged on their gewgaws.

The mischievous effects on the settled regular business of a country, from excessive importations, arising out of particular causes, such as a country being instantly shut out from some market heretofore enjoyed by her; sending the excess here, gluts the market, and stagnates in the hands of the manufacturer, many months produce: this is a serious evil, and Britain either has guarded herself against this, or soon seizes the event, and by new duties, turns it to the account of her revenue; some such provision should be made in the United States; I am strongly impressed with the opinion, that from this will come the ruin of many of our manufacturers, and even some of the manufactures themselves; but 50 per cent. would extend to them, a fair chance of success, and nothing farther should be tried at present.

In such a population as Philadelphia, there are now numbers not employed, who in the existence of manufactures would gain considerably; and the aggregate of their annual wages, would be an immense sum added to the nation's wealth.

Indeed, it has been stated by some political writer to Napoleon, that it was in the villages of France, that he could conquer the British navy. Bonaparte was a better judge of military affairs, than of political economy, and rejected the plan. Industry is not so brilliant as military exploits, but its effects are frequently more successful, always safer, and it increases the resources to support the latter. If congress does not very soon act decidedly in favour of manufactures, the spirit will generally languish, and probably some of the establishments perish: which would be a circumstance much to be regretted, as in this part of the controversy with the enemy, we have been surprisingly successful.

I am respectfully,

J. R.

* It would appear to me protection quite sufficient, if beginning with 50 per cent. 5 per cent. were taken off every two years, till the permanent duty should be reduced to 15 per cent. T. C.

CHROMAT OF LEAD.

Mr. William Hembel, jun. of Philadelphia, having had much experience in making the chromat of Lead, I wrote to him for his process; which, with the liberality so common among scientific Chymists, he has been good enough to send to me. I have seen no specimens of the colour equal to what he has made. T. C.

DEAR SIR,

THE great difficulty in preparing the Chromat of Lead, is to preserve an uniform colour during the whole precipitation with nitrate of Lead. Vauquelin, Murray and other writers, found the difficulty so insurmountable, that, they concluded, Chromat of Lead could never be made subservient to the arts.

In my first experiments, I experienced similar disappointments; prepossessed with the opinion of Mr. Vauquelin, I concluded, that, the different colours of the same precipitation, were occasioned by different quantities of alumina, or magnesia, which the chromic acid carried down, by an affinity too strong to be interrupted, otherwise than by the regular order of analysis.

It will however be obvious to you, that such a proceeding would be totally incompatible with the despatch of the manufactory, even supposing that the manufacturer possessed the talents to conduct such complicated processes, which it is often necessary to modify, from causes which can only be appreciated by the practical chymist.

Disappointed in every attempt to procure a deep and uniform colour, I finally separated all the earths, previous to adding the nitrate of lead; under the persuasion, that when they were removed no obstacle would remain to prevent an artificial product being obtained equal in beauty to the natural: but the result disappointed my expectations, and at the same time instructed me, that it was not the earths only, but *carbonic acid* also, which had hitherto baffled my endeavours.

I had long satisfied myself, that no quantity of acid was sufficient to expel all the carbonic acid from alkalies, in the time allotted to processes of the laboratory, unless the solution was heated to the boiling temperature at the same time; and reasoning from that fact, I concluded, that the *carbonic acid*, which the alkali of the nitre acquired during the fusion of the mineral, combined with part of the nitrate of lead, which precipitating with the chromat

of lead, occasioned all the varieties in shades, in which the pigment was exhibited in our experiments. Under that impression, I digested a portion of the precipitate which I had obtained in former experiments, in cold diluted nitric acid, a slight effervescence ensued; and the colour immediately improved to a lively orange yellow: nearly equal to that which you think superior to any you have seen prepared.

The result of the above experiment suggested the following processes. The first I have verbally communicated to several persons, who have undertaken to prepare the pigment for sale: but, from the inferior colour which they produce, I fear that more knowledge of chymical processes is necessary to enable a person to conduct the second than is common to mere manufacturers.

1st. Reduce any quantity of chromat of iron to a powder sufficiently fine to pass through a sieve of the finest bolting cloth; triturate half its weight of nitrat of potash, and mix the two powders intimately together. Introduce the whole into an iron pot (I use the pot of a cast iron glue-kettle, having a cover) and add as much water as will reduce the whole to the consistence of thick paste. Place the pot on some lively coals, and cause the water to boil, stirring the whole occasionally with a stick, until the mass is dry; then introduce the pot into an air furnace, and heat it about a cherry red; but be careful not to increase the temperature as long as oxygen gas is evolved, otherwise the pot will be melted. The escape of oxygen gas will be made manifest by holding a live coal at the juncture of the pot and cover; as long as oxygen escapes, the coal will burn with increased splendor; when the splendid combustion ceases, the fire should be augmented until the pot is of a very bright red, and kept at that temperature about one hour. The pot should now be suffered to cool in the furnace, to prevent its cracking by a sudden change of temperature; and when cold, it is to be well wiped on the outside, and placed in a tinned kettle containing a large quantity of water, which is to be boiled until the mass can be detached from the pot; when the latter may be withdrawn. The boiling must now be continued for half an hour, occasionally bruising the hard mass at the bottom of the kettle, after which it may be withdrawn from the fire and suffered to settle for a few minutes. When the supernatant liquid is clear, it is to be decanted into a convenient vessel, and the kettle filled with fresh water, which must be boiled on the residuum, and the process repeated as often as the liquid appears to be strongly coloured. After a few boilings, the liquid (if the quantity of water is large) will

be so faintly coloured, that a further continuance of the boiling will be a waste of time; then the remainder, which consists of oxyded iron, may be thrown away, and the kettle rinsed clean. A part of the liquid is now to be introduced into the kettle, and briskly boiled, supplying the waste as it boils away, until the whole is introduced therein; it should then be concentrated until it is nearly at the point of crystallizing when cold; when it may be thrown on a filter, to separate the iron which may remain suspended therein, together with the magnesia which will have precipitated.

On gradually adding nitric acid to the filtered liquid, a precipitate will appear, which is the earths held in solution by the potash of decomposed nitre, and disengaged by the acid combining with the alkali; but attention must be paid not to add the acid in excess, otherwise the precipitate will be immediately re-dissolved; the better way will be to add less acid than is deemed necessary, to separate by filtration the precipitate which may appear, and to the filtered liquid add fresh acid, then filter again and repeat the process as often as a precipitate falls; by that cautious proceeding the separation of the earths may be considerably approximated, but not entirely effected.

Nitric acid is now to be added until the solution tastes sensibly sour; it is then to be boiled in a glass vessel, and whilst boiling a few drops of acid are to be added as long as an effervescence or even globules of air appear to rise from below the surface of the liquid, on each addition of nitric acid; when they cease, the solution must be briskly boiled for fifteen or twenty minutes, which will completely expel the *carbonic acid* which may remain.

Into the above solution, either hot or cold, a solution of nitrate or acetate of lead is to be poured so long as a precipitate appears: *or the acetate, if clean, may be added in powder or lumps*, which I think preferable, as we thereby avoid the bulky solution which is so very inconvenient where capacious glass vessels are difficult to procure. When the precipitation is completed, it should be thrown on a filter and well washed, by filling the filter fifteen or twenty times with boiling distilled water; the water being suffered to run entirely off, before the filter is again filled. As the beauty of the colour and the property of drying quickly will greatly depend on its being well washed. It may be interesting to add, that I have found strong boiling of river water a good substitute for distilled; the water was boiled for half an hour in an open vessel, then suffered to cool, it deposited a considerable sediment of vegetable matter, and in winter, some carbonate of lime, which

was separated by filtering; the water was again boiled in a clean vessel, and used hot, as above directed.

After the lotions are concluded, the filter may remain in the funnel for 24 hours to drain; the funnel being covered with paper, to prevent the pigment being injured by dust, &c.; the paper will then bear being raised without danger of tearing, and may be laid on a chalk stone to dry, with a sheet of bibulous paper laid on its surface.

My second process, which furnishes the finest specimens, is as follows:—The mineral is treated as in the former process, except that instead of adding *nitric acid* to separate the *earths from the concentrated solution;* I add a saturated solution of *muriat of ammonia*, an abundant precipitate immediately appears, the muriat of ammonia is added until it ceases; the whole is then thrown on a filter: by this means I free the solution of *all the earths.* Into the filtered liquid I add nitric acid until it is sensibly sour, and boil *immediately;* whilst boiling, a few additional drops of acid are added, to ascertain whether the liquid contains any *carbonic acid*, if an effervescence ensues, or small globules of air are perceived to rise from below the surface, more acid is added until they cease, when clean acetate of lead in powder is *immediately* added, as long as chromat of lead is precipitated. The chromat is then separated by filtration, and the washing, &c. conducted as in the former process.

This last process (if properly conducted) always produces deep orange colours of great beauty. Of six specimens which I prepared, no difference could be observed in the shades, by the most discriminating eye; but it is indispensable to success, that there be no delay, after the *carbonic acid* is expelled by adding nitric acid and boiling: as the muriatic acid of the muriat of ammonia, decomposes part of the chromic acid, oxymuriatic acid gas is abundantly evolved, and the solution changes rapidly to a dark yellowish green, the decomposition however is only partial; yet the least delay in adding the acetate of lead would render it general, and thus defeat the previous labour.

With respect to the permanence of the colour, I cannot say much from my own experience; the opinion of artists I find different on the subject. I will however observe, that no inference should be formed from the specimens which have been offered to the public; they are all contaminated with *carbonate of lead*, a pigment which is well known to blacken, the instant it comes in contact with sulphuretted hydrogen gas, or the effluvia from pu-

trid animal or vegetable matters; to that change I attribute the deterioration which was experienced with the chromat of lead hitherto used. I will further observe, that I think oil made drying by oxyded lead, should not be used, owing to the great affinity which the oxyds of lead have for carbonic acid, particularly when in contact with substances capable of affording that acid by decomposition. I will not say that I know the oil is *partly* decomposed, but I *think* I have observed the phenomenon: a board was painted with the pigment and poppy oil, it appears to stand very well.

In the above, sir, I have endeavoured to lay before you the reasoning which led to the processes I now pursue; should you publish them, no person will be disappointed who follows them faithfully.

Your friend,

WILLIAM HEMBEL, jun.

THOMAS COOPER, Esq.
Professor of Chymistry,
Carlisle College.
June 28th, 1814.

COOKERY: A SALMAGUNDI.

Νυν δε μνησωμεθα δορπου
Καί γαρ τ'ηυκομ@ Νιοβη εμνησατο σίτου
Τηπερ δωδεκα παῖδες ενι μεγαροισιν ολοντο.

Now let us think about supper: for the fair haired Niobi did not forget her meals, although she had twelve children lying dead in her house.

SO spake the swift-footed Achilles to king Priam, who came to beg the body of his son Hector. Harry Fielding, too, has a dissertation in Tom Jones, to prove that even violent love will not take away the necessity of eating, or entirely destroy the appetite for a good dinner. This, in my opinion, is also proved by the common practice in every country, of drinking to your mistress's health, which presupposes good eating to be washed down with the good wine used on such an occasion. The same inference may be fair-

ly, though indirectly, deduced from the old proverb, "Excessive sorrow is exceeding dry." Hence I may conclude it as a common practice, that whether a man be in grief or in love, he will eat a good dinner if it be set before him, and the stomach calls for it. Montgomery, the poet, thinks with me in his verses while in prison.

"When drest I to the yard repair
And breakfast on the pure fresh air:
But though this choice Castalian cheer,
Keeps both the head and stomach clear,
For reasons strong enough with me
I mend the meal with toast and tea.
Now air and fame, as poets sing,
Are both the very self-same thing,
Yet bards are not cameleons quite,
And heavenly food is very light;
Who ever din'd or supped on fame
And went to bed upon a name?"

So in the old song, Bacchus very shrewdly asks Appollo,

"Who ever got fat at the sound of a string?"

Now, every common practice, that is, a practice universally followed in all ages and nations, may be considered as a law of nature and of nations. Thus, Grotius, L. 1. cap. 1. sect. 12. parag. 1. sub fin. *Juris naturalis esse colligitur, id, quod apud omnes gentes, aut moratiores omnes, tale esse creditur. Nam universalis effectus universalem requirit causam; talis autem existimationis, causa vix ulla videtur esse posse, præter sensum ipsum communis qui dicitur.** In support whereof, according to the laudable practice of his day, (now almost suppressed through the ignorance, idleness, or plagiaristical concealment of modern authors) he gives us eleven quotations: to wit, one from Hesiod, a case directly in point, as the lawyers say; running upon all fours; *proprium quarto modo*, as the logicians have it; together with a dictum of Heraclitus; three passages from Aristotle; one from Cicero; one from Seneca; one from Quintilian; one from Porphyry; one from Andronicus Rhodius; and one from Plutarch. To make up the baker's dozen, he adds in a note, another from Aristotle; another from Seneca; and another from Quintilian; and throws

* This is the foundation of the wonderful discoveries in Dr. Beattie's Essay on Truth.

into the bargain, still one more from the last author; and a spick and span new citation from Tertullian. His annotator, Barbeyrac, out of sheer envy, spite, and vexation, because these annotations of the author, rendered unnecessary those of his commentator, most seditiously, and in contempt of his superiors, declares, *omnia ista loca, si duo priora excipias, parum ad rem referunt.* In the same prudent spirit of leaning upon sage authorities (upon a broken reed as Horn Tooke, of seditious memory, would call it) my lord Monboddo, having asserted, that "when a man opines, he must opine some thing; and therefore the subject of an opinion is not nothing," does not venture to turn out into the world so profound an observation, unprotected; he therefore fortifies it by the authority of Aristotle. So in later times, the very learned Dr. Magee, now professor of mathematics in the college at Dublin, proves the doctrine of atonement and vicarious suffering, the absolute inefficacy of repentance, and that without the shedding of blood there can be no remission, by the general prevalence of human sacrifices throughout the ancient and modern world. This is a doctrine, which if an unlearned christian finds clearly laid down in his bible, he adopts at once, and looks no further. Not so the learned doctor. He brings his case into court with a full determination to make security doubly sure. He therefore cites, as witnesses in his behalf, authors of all ages and nations, ancient and modern, of all ranks and descriptions, original and at second hand, in most erudite and overwhelming confusion. To be sure, had he arranged and marshalled them either in order of date, or reputation, or language, or subject matter—had he distinguished between original and hearsay testimony, or between the rules of credit or credibility, he might perhaps have escaped some legal objections to testimony, but he would have lost ground perhaps in the effect and grandeur of display.

First he offers to the court, Herodotus, and Porphyry, and St. Augustin, and M. de Paauw: then Sanconiathon, as quoted by Philo, as quoted by Eusebius. Then Keisler the modern, and Diodorus the ancient, and Manetho the Egyptian as cited by Plutarch. (He forgot Berosus, who generally composes one of the firm of Sanconiathon Manetho and Co.) These are backed by Murtadi the Arabian, who is supported by Mr. Maurice the Englishman, and M. Savary the Frenchman. Then we have an account of the oblations of the Chinese monarch Ching-tang from Martin's historia Sinensis: and those of the Persians from Herodotus, and Xenophon, and Arrian, and Strabo, and Suidas, whose evidence (to clear it from all objection) is tri-

umphantly supported by Monsieur Barnaby Brisson! Then, lest the Rev. Mr. Maurice should be deemed insufficient, he is corroborated by Orme, and Sir W. Jones, and Mr. Wilkins, while Holwell and Dow who have hitherto passed through the world with good name, fame, credit, character, and reputation, are on this occasion unmercifully lashed by the learned Doctor. The jury are then enlightened upon the devotional practices of the Druids, as detailed to us, by Diodorus Siculus, and Lucan, by Cæsar, and Tacitus. These religious acts of the Druids who sacrificed their *enemies taken in war*, were nothing however to the pious orgies of the Greeks, who cut the throats of *their friends before battle*, as we are told by Phylarchus, and Pausanias, and Fulgentius, and Apollodorus, and Plutarch, to say nothing of Suidas, who whispers a few greek words in assent. Upon a similar subject, Plutarch, Livy, and Pliny, are kept in countenance by the authors of the Universal History, and by Porphyry. Evidences now crowd thick upon us; some are introduced for the first time, others for a second examination: Herodotus, Strabo, Jornandes, Cicero, Cæsar, Procopius, Tacitus, Pliny, Sanconiathon, Plato, Silius Italicus, Justin, Ennnius and Diodorus, succeed each other *velut unda supervenit undam.* All these testimonies, a man well red in indexes, might perhaps have mustered with great labour, as Dr. Magee has done: but the Doctor is no common writer, or every day reasoner: he aims to "snatch a grace beyond the rules of art," and to fortify the scripture doctrine of atonement, he boldly appeals to the practice of the Canaanites! (Lev. xx. 23.) The Hivites, Hittites, Amorites, Jebusites, Perizites, and so forth, are passed over. Then we have the corresponding customs of the Arabians again; of the Cretans, Cyprians, Rhodians, and Phocæans; with those of Chios, Lesbos, Tenedos, and Pella, from Porphyry as quoted by Eusebius, and from Monimus as retailed to us by Clemens Alexandrinus. So that the universality of the principle and practice of atonement and vicarious suffering, in the heathen world, "cannot reasonably be questioned." Lest however it *should* be questioned by some unbelieving wight, the learned Doctor goes on more fully to strengthen his positions, by Euripides, Tacitus, Plutarch, Pliny, and Plato, attended by Professor Meiners and Dr. Cudworth, who vouch to warranty all the ancients, wherever their testimony can be pressed into the service.

Then the Doctor proceeds to shew that the same principle and practice has obtained among all the most polite and civilized bar-

barians and savages of modern days. Mr. Thorkelyn the advocate of the slave trade, leads up the train of witnesses: he is succeeded by Ditmarus who is called in by Loccenius. Then come Adam Bremensis, and St. Boniface, Mallet, (a sad rogue) Jortin, and Fleury, as to the practice among the northern tribes of Europe. Then he glances over the various nations of Africa, and the islanders of the South seas, of Ota-hai-te and Tongataboo, concerning whom we are presented with the testimony of Snellgrave and captain Cook. As to the American savages at the first discovery of this continent, Acosta, Gomara, Antonio de Solis, Clavigero, give ample testimony. The East Indian rites and ceremonies of similar description are attested, by Maurice, Mickle, and Crauford: by Dow, Holwell, Grose, and Buchanan: not to mention that indefatigable and unequalled citer of authorities, Professsor Meiner's,* who, though he had long ago forestalled the Doctor, is kept too much in the back ground.

* Dr. Magee is original only in his mode of argument: not so in his body of quotations, as the following extract may shew, from Meiners' Syllabus of a History of all Religions.

SECT. VII. Nor was it less universal a matter to offer peace offerings upon misfortunes, or to endeavour to avert the consequences of misconduct. Expiatory sacrifices, and trespass offerings are therefore to be met with amongst all the nations of the new and old world.* Nay, they have supported themselves amongst such nations as have long since banished every kind of bloody rite.†

* By the Ægyptians, Herod. Plutarch. l. c. et Schmidt, *p* 312. By the Israelites, 278, 79. Outram, *p* 118. Mich. Mosaic Laws, *v* 98 3. Mos. 5. *v*. 2, 3. also c. 4. and 16. By the Greeks, Plat. de Republ. ii. *p*. 102. edit. Massey. The Romans, Liv. c 31 c. 12. L. 34. c. 55. L. 28. c. 11. L. 29. 14. Plutarch. in Coriol. ii. *p*. 129. By the Negroes, Loyer, *p* 248. De Bry, vi. 20. And the Siberian Heathens, Georg. *p* 389. By the savage Americans, *p* 348. Charlev. Jour. By the Amboinese, Valent. iii. 10. By the Hindoos, Roger, i. 5. ii. c. 15.

† By the Heathen Greeks, and Mahometans, Shaw, *p* 333. Guys, i. 466.

SECT. VIII. The causes which led men to offer other things, inclined them likewise to offer up men; they therefore either offered up themselves willingly, or their brethren against their wills. The former was commonly done, for three reasons; either to follow certain persons into another state,* or to appease their angry gods, or to enjoy the felicity of another state earlier, and in a greater degree.

* This was done by all the Scythian and Celtic nations, Cæs. vi. 21. Tav. c. 27. German. Herod. V. Pellout. 10. 113. 119. Conner. i. 81. 83. Tavern. ii. 162. Historic. Fragm. *p* 126. By the Hindoos. In the Indian ocean, Recueil des Voy. des Hollandois.

So that there can be no doubt upon earth, but the principle of vicarious suffering, and the practice of human sacrifice, is, according to the rule laid down by Grotius, and fully adopted in principle by Dr. Magee, part and parcel of the law of nature and nations.

SECT. IX. Compulsive human offerings were made either for the sake of obtaining health, a victory or some other blessing; or to thank them for favours already granted; or to learn future events from them; or to appease departed souls, by sending their friends and servants after them; or finally to appease the anger of the gods. (See the notes.)

* Scandinavians, Herod. iv. c. 94. Barthol. *p* 230. 700. The Greeks, Lucian, i. *p* 466. The Negroes, introduc. Projart. *p* 269-86-99. The Inhabitants of Paos, and Pegu, Sonnerat, ii. 39. Rhodes, *p* 349. The American Savages, i. 120. Coreal. The Peruvians, Acosta, *p* 229. The Tunquinese, Ovingt. ii. *p* 52.

† Upon this principle it was that they brought human offerings to Queen Amestris, vii. 114. Herod. The Goths, Jornand. ap. Grot. *p* 617. And Procop. ii. c. 25. Keisler, *p* 134. The Galatians, *v. p* 355. Diod. Wessel. The Peruvians, Acosta, *p* 227. The above mentioned savage nations in Africa, ll. cc. and Snellgrave, *p* 36. 54. The Romans, Dio. Cass. l. 43. c. 24.

‡ Strabo mentions this of various nations, iv. 303. vii. 451. xi. 768. This also happened on the island of Mona, xiv. 30. Tacit. among the old Northern nations, Mallet, *p* 84. In Peru, i. *p* 52. Zarate. And in the Mysteries of Mythras. iii. c. 2. Socr. Hist. Eccles.

§ This also took place amongst the old Celtic and Northern nations, Her. iv. 71. Mallet, *p* 213-214. Barthol. *p* 506, 507. Also amongst the Greeks and the Romans, Homeri Ilias, XXIII. *v* 179. Just. xi. 2. Virg. Æneis, x. 517 533. xii. 948. Varro ap. Serv. ad. iii. 67. Farmer, *p* 441. Also among the Mahrattas, *p* 126. Histor. Fragm. Also amongst the Negroes, i. 315. Oldendorp. Cavazzi, i. 250. 381. 391. 401. ii. 122. 168. Des Marchais, i. 315. ii. 74. Projart, *p* 299. 329. Also under the Moguls and Chinese, Gentil. ii. 151. Voy. au Nord, vii. *p* 58. Also amongst the North American savages, Charlev. *p* 247. The Taencas, Voy. au Nord, *v* 129. Also amongst the Peruvians, and Inhabitants of Mexico, Acosta, *p* 209. 211. 227.

‖ This was the custom amongst the old Celtes and Sclavonians, Anton. *p* 64. Tacit. de Mor. Germ. c. 9 et 39. Barthol. *p* 228. 323, 393, 394. Mallet, *p* 83. 86. The Taurians, Her. iv. c. 103. The Galatians, Just. L. 26. c. 2. Diod. *v. p* 355. Ed. Wessel. The Gauls, Cæsar, vi. 16. Massagetæ, i. 216. Herod. The Greeks and the Romans, Dionys. Halic. Antiq. R. i. 38. Plut. ii. 366 et seq. iii. 625. vii. 102. 143-45. Lact. Inst. Div. i. 21. Plin. L. 28. c. 2. Suet. in Calig. c. 27. in Ner. c. 36. Porph. de Abst. ii. c. 54-56. Pausan. iv. 9. vii. 19. 21. viii. 2. Meursii Lect. Attic. iv. 22. Miscel. Lacon. ii. 14. Farmer, *p* 441. The Phœnicians and Carthaginians, Justin. xix. 1. xx. 14. Plut. vi. 633-35. The Ægyptians, Schmidt, *p* 277. The Tunquinese, Rhodes, *p* 119. The Inhabitants of Borneo, Forrest, *p* 368. The Negroes, Loyer,

I confess I was not only much instructed and greatly edified, but also, in no small degree, solaced and comforted by this elaborate dissertation of Dr. Magee; in as much, as it tends strongly to prove, that the kings and conquerors ordained under the dispensations of providence, to superintend the government of the various nations of the earth, are by no means deserving of the ignorant obloquy which it is too common to throw upon them; and that even the human sacrifices of Bonaparte himself, may possibly proceed from his deep sense of religion, and his profound respect for the laws of nature and of nations.

It is surely among the desiderata of human knowledge, that Dr. Magee should apply his new method of theological demonstration, to mathematical instruction, so much more luminous and convincing as it seems to be. If he does not secure his invention in the patent office of his own country, I greatly fear that some ingenious Yankee speculator in patent rights will forestal him, and claim it as a notion, the genuine offspring of some cisatlantic brain. I cannot say how far Dr. Magee coincides with the limitation of Grotius, *saltem apud moratiores omnes;* but be that as it may, I do suppose the learned Professor, in his adopted character as prochein amy of Mrs. Bull, will be as fairly entitled to remuneration as Dr. Horsley; and if Hurlo Thrumbo were alive, he would certainly obtain it. In our state, the *circular mileage* of these witnesses, so liberally allowed by the Legislature of Pennsylvania even to the President Judges, would form a very pretty item in the bill of costs,* made out in the Doctor's favour, and amply re-

248-49. Oldend, i. *p* 329. The Floridans, Peruvians, and Mexicans, Acosta, 227. 234. Gage, i. *p* 154. The Otaheitians, Forster's Observations, *p* 476. Cook, i. 185. The Inhabitants of Madagascar, ii. 52. Sonnerat. The Bramins and Hindoos, i. 186. Sonner. The Inhabitants of Formosa, Psalman,* *p* 43. 60. The Chinese, Memoir. concer. les Chinois, ii. 400. In order likewise to appease the Gods, they murdered or exposed sick persons. This was done by the ancient Persians. See my Dissertation on the Religion of the Persians. This is likewise still done by the Mingrelians, Lamberti, *p* 153. The Hindoos, Ives, *p* 26. The Hottentots, Beschryv. i. 226. The Kamschadales, Steller, 271. 295. The nations on the Oronoko, i. 333. 335. Gumilla. *(Psalmanasar deceived Meiners for a time. T. C.)

* It will be necessary for the sake of some of my readers, to explain this allusion in my correspondent's paper. It relates to the method of making out the bill of costs of sheriffs and constables, who summon witnesses to court, and who are entitled to mileage only according to the nearest route. In the present year, 1814, also, an act passed the Legislature of Pennsylvania, allowing circular mileage to the President Judges of the court of Common

pay his laborious researches, though motives of secular interest were far, no doubt, from the Doctor's thoughts.

Blessings on the whole tribe of quotation-mongers, from Grotius to Burton, from Burton to Meiners, from Meiners to Magee,

Pleas, at the same rate as is allowed to witnesses who attend, or to constables who summon them. At the formation of the present constitution of this state in 1790, the salaries of the judges were settled at their present rate of $ 1600 a year (mileage lately allowed, amounting in this district to about forty dollars a year, only excepted.) At that time, the wages of the members of assembly, were two dollars a day: the members of assembly afterwards raised their own wages to three, and last session to four dollars a day. Had this rate of wages been appointed for the succeeding session, no person would have found much fault with it; but the implied contract between the representatives who voted themselves entitled to four dollars and took it, and their constituents at the time of election, was certainly for no more than three dollars. In common transactions, and among decent people in common life, this would have been considered *a fraud.* Had the wages been raised to eight dollars a day, in consideration that the session should break up before the frost breaks up, and continue but half the usual time, that half only of the usual number of laws should be passed, and half the hours only wasted in ignorant and noisy declamation, the public would indeed have been greatly the gainer.

From the year 1790 to this time, the business of the Judges has nearly doubled, the price of all the necessaries and comforts of life have doubled, and these men who have doubled their own wages within the same period, think it sufficient to add forty or fifty dollars a year in the degrading shape of post boy's pay, to the salaries of their Judges!

Hurlo thrumbo: Lord Chancellor Thurlow. The following dialogue actually took place at his Lordship's table. He was called out during dinner: when he returned, one of his guests said, "pray my Lord, if I may be so bold, "which of the cabinet ministers has disturbed your Lordship's devotions at "dinner?" "Cabinet ministers! I wish they were all at h— with the puppy Pitt at the head of them! No. It was the Archdeacon of St. Albans; he came to pester me for the Bishopric of St. David's, and talked me to death about his services to mother church. The canting rascal cares no more about the old b—h than I do: but he has fought faithfully against old gunpowder (Priestley), and he deserves the vacancy." Horsley led the pack so profitably, that it is the fashion for expectants to yelp in.

My correspondent evidently levels his remarks, not at the doctrine, but the method of proof, employed by Dr. Magee; otherwise, this part of the paper would be inadmissible. He may laugh if he pleases at Dr. Magee or myself, or any other of the laborious tribe of index-hunters: but I have nothing to do with theological opinions. I confess, I have always thought, that the only allowable way of establishing Christian doctrine, is by the Christian Scriptures; all other proofs, are at the best unnecessary. Is the tenet you advance plainly revealed in the Bible? If it be, the Bible is sufficient for a Christian: if it be not, can profane writers establish it? Do you distrust the authority of the scripture, that you seek elsewhere for support?

and from Magee to myself! Peace to the souls of them that be at rest, and prosperity to the living! Are not we the exclusive supporters of order and regular government? the very props and mainstays on which must rest the authority of every crowned head in Christendom? ay, and in Pagendom also? Are not we the only class of literary knight errants, who, despising all argument, pay passive obedience and non-resistance to all authority? How can the professors of law and physic—nay, how can the professors of divinity do without us? Is not our motto, *Stare decisis?* A bas les agitateurs? Down with the innovators? Away with the fallible pretensions of human wisdom, and the false lights of that ignis fatuus, human reason?

Moreover, although our storehouses are professedly repositories of stolen goods, yet we keep them for the benefit of the literary world. Although we do enable those who steal from us what we stole from others, to shine in borrowed plumes, like the classical essayists of London, who pillaged without mercy that amasser of other men's wealth Robert Burton—or like the Edinburgh reviewers, who dress themselves out in the cast-off cloaths of Jeremy Taylor, still we mainly contribute to the classical gaiety and literary finery of the day: and although the sober traveller may smile at the gaudy appearance of ancient frippery on modern linsey-woolsey, yet, *sunt quas arbusta juvant*, there are who do not dislike even the white, red and yellow trees before the door of a Dutch

Dr. Magee says to his reader, I can prove the doctrine of atonement from the word of God, and from M de Pauw. Can you indeed? Then, for mercy's sake, spare us dear Doctor, the mortification of M. de Pauw! Will you drench us with ditch-water after Tokay?

> And thou Dalhousie the great God of war,
> Lieutenant Colonel to the Earl of Mar,

is sublimity itself in comparison to such an attempt. Moreover, if the practice, whose universality he labours to establish, be indeed, as he calls it, a horrid superstition, what aid can it afford to a doctrine of revelation? Is it possible he could be blind to the very obvious injury his opinions might receive from his quotations?

The truth is, that Dr. Magee's book is manifestly written, to serve, not the spiritual interest of the church, but the secular interest of Dr. Magee. Writer is introduced treading upon the heels of writer; quotation is heaped upon quotation; reference urges reference; criticism of sarcasm succeeds to criticism of contradiction; and authority is backed by authority, in endless and useless succession; meant indeed, to display the extent of the Professor's reading, but affording evidence still more decisive of the narrowness of his judgment. T. C.

house-wife, and the ever-green broad-brims and yew-tree tobacco pipes that adorn the garden of myn heer, her husband.

I have been led into this digression because not having been able to furnish you with a drawing of a kitchen fitted up to my mind, I sat down with a positive determination to shew the great importance of eating generally, and of good eating particularly, from the precepts and practices of divers great authors, who have incidentally or expressly treated this important subject. I meant to have rendered my position luce clarius, although by reflected light; and to have fortified and protected it by a seven fold shield of impenetrable authorities. But I have been induced to confine myself to narrower bounds, for reasons that I shall presently mention.

There are many passages, moreover, in classical and other books of importance, that can only be elucidated by a commentator who understands something of the history of eating. Thus, when we find how greatly people in general abhorred the practice of eating with unwashen hands, this can only be explained by shewing, that the Jews at that time, like other nations, had no knives, forks, or spoons, but eat with their fingers, as the Arabians to this day feed upon their cuscusoo. When our Lord desires the servants at the marriage of Cana in Galilee to bear unto the master of the feast, I apprehend this is a wrong translation, for the wine was under the controul not of the entertainer, but of the elected toast-master, the *arbiter bibendi: quem Venus sorte dixerat.* So when we read of the favourite Apostle who reclined in our Saviour's bosom, this can only be understood by a reference to the *Triclinia*, or couches, and the mode of reclining upon them: chairs being used at that time by females only; who afterward adopted the couches of men, when they began to throw aside the modesty of women.

Many questions of great importance in political economy also depend upon scientific and historical knowledge in eating. Thus, the introduction in England of napkins and silver forks to each plate, and of separate tumblers to each person at dinner, is a custom introduced even in families of rank in England within 50 years; and is by no means general even among the opulent of the middling classes to this day; while in France, the poorest person has his silver four-pronged fork, his napkin, and his separate glass tumbler. This arises from the mode of cookery peculiar to each nation. In France, they feed chiefly on soups, and on meats stewed or boiled till they are quite tender: hence, a knife is not so necessary an article in France as in England, but spoons and four-

pronged forks are essential, and cleanliness requires them to be of silver. Hence also, the French take up their food with their four-pronged fork in their right hand, while the left, holding a piece of bread, sweeps up the soft food upon the fork. Hence the necessity of napkins and separate tumblers, because a Frenchman's fingers are so often greasy at dinner time, while an Englishman has no occasion to soil his, in any degree.

These remarks will furnish a solution to the following questions.

1st. Why has the linen manufactory been cultivated in France to so much more perfection and so much greater an extent than in England?

2dly. What is the principal cause, why Great Britain is the greatest manufacturing nation in Europe?

3dly. Why is it that the system of paper credit, is more prevalent in England than the rest of Europe?

4thly. Why is the hardware of Great Britain, particularly the cutlery, superior to the same manufacture in other countries?

5thly. Why is the system of boxing more common in England than elsewhere, and the quarrels of the common people less murderous?

6thly. Why are the English better sailors than the French?

7thly. Why do the French excell in the manufacture of snuff?

8thly. Why are the French the best baker's in Europe?

9thly. In what particular has a French army an advantage over an English one?

10thly. Why is coin always plenty in France, and not in England?

11thly. Why are the English better book-binders than the French?

12thly. Why do the French, cæteris paribus, print books cheaper than the English?

These questions might be extended, but they are sufficient to shew the important bearings of my subject; and that no man can pretend to useful knowledge of almost any kind, unless he have knowledge in the science of eating also. And now to their solution.

1st. Why has the linen manufacture been cultivated in France more extensively than in England? Because from their mode of eating, dependant on their mode of cooking, there is a much greater demand for, and consumption of napkins and table cloths.

Their mode of washing linen by means of beaters also, greatly contributes to its consumption.

2dly. Why is Great Britain the principal manufacturing nation in Europe? Because their taste in eating has driven them to the necessity of using stone coal for fuel; and of perfecting their iron manufactory, on which all other manufactures depend.

The people on the continent of Europe, prefer small dishes, soups, and stews, which can be cheaply and conveniently cooked with charcoal. The English have from time immemorial been attached to large joints, particularly of roast meat. This has driven them for cheapness to the use of coal, the cheapest of all fuel, and the very ground work and basis of all manufacture.

Their large joints require knives and forks, of large dimensions, and of good temper: hence, as an article in perpetual use three or four times a day, neatness, goodness, and cheapness early found their way into this branch of the iron manufacture, and gradually extended itself to every other branch.

3dly. Why is it that the system of paper credit is more prevalent in England than the rest of Europe?

Paper money will be first used, and more extensively used, in those places where gold and silver are comparatively scarce. It will be long before it comes into play, in a country where precious metals are abundant. The precious metals will be abundant in those countries, where they are in the greatest demand and in general use for domestic purposes, and the common wants of life.

Owing to the English taste in eating, and their gross method of cooking, steel knives and forks have banished silver. For the latter metal is not fit to cut up a buttock of beef, or a sirloin. While in France, the use of soups, stewed meats, and salads, have rendered a silver four-pronged fork and a spoon necessaries of life to every man, woman, and child in the country. This has extended the use of silver to evey other article of the table: thus, plates, dishes, and tureens—plateaux, waiters, and candlesticks, there, are silver. In England, the neatness and cheapness of the pottery manufacture, especially since it has been directed by the taste and science of Bentley and Wedgewood, has superceded, even among the English nobility, the necessity of silver services. Then again, the system of plated goods in England, dependant on the general state of their manufactories, as controuled by their collieries, has banished solid silver from their houses: to which a very inefficient and defective police has greatly contributed. Hence, in France the precious metals, particularly silver, have al-

ways been and still are in great abundance; in England the reverse has been the case. Hence real money, gold and silver, to this day, is the only circulating medium of the former nation: while in England, the precious metals are nearly banished, and the iron age prevails. The hoarding of the precious metals during the reign of Robespierre and revolutionary principles, and the issue of paper money in France at that day, hardly forms an exception to the general remark.

Hence, perhaps, if the females of England had been better skilled in French cookery, the bank of England need not have stopt payment.

4thly. Why is the hardware, particularly the cutlery, of England, so much superior to the same manufacture in other countries?

Because it is evident, that the gros morceaux, that load the English tables, require this superiority: and the daily use of cutlery at meals, instead of silver, naturally produces more demand, more competition and more skill.

5thly. Why is the system of boxing more common in England than elsewhere, and the quarrels of the common people less murderous?

This is owing to the fashion of feeding. In England, the knives do not shut. The meat requires them to be too large for the pocket: those who find you meat, find also knives to cut it with. On the continent, every man carries in his pocket his own couteau. The persons who find meat, find forks only. Hence abroad, a vulgar, quarrelsome brute, has always his knife—his snickersee, in his pocket to resort to; an Englishman has nothing to betake himself to but his fists. Dr. Bardsley, of Manchester, has written a very learned, a very elegant, a very ingenious essay in favour of boxing, which some day or other I will republish.

6thly. Why are the English better sailors than the French?

The English are better accustomed to relish and digest the hard and solid provisions, on which a sailor must subsist. This is not the only, but it may reasonably be regarded as one cause.

7thly. Why do the French excel in their manufacture of Snuff?

Because it is necessary to suppress and obtund the odour of garlic, rocambole and shalot in their houses and their streets, arising from its predominance in their cookery. Does their more extensive use of perfumes arise in any degree from the same cause?

The French also appear to me better botanists and gardeners than the English, owing to the greater variety of vegetables employed for culinary purposes: by the way, the Abbe Correa, informs me that the purslain, phytolacca oleracea, a very good culinary vegetable, and commonly used in France, is to be found in all the streets of Lancaster, Pennsylvania, and the amaranthus viridis (or else blitum, *Careless)* is common at Carlisle. The dandelion, the sow thistle, the lambs-quarters, the poke, the sorrel might also be used in places where gardens are scarce with us: that is every where in this state. I greatly regret the want of truffles, morills, and garden mushrooms in this country, where for the most part there is no taste but for tables so crowded as to sate the appetite by the very sight of the dinner; and where the delicaces of an European entertainment are little known. But I do not feel inclined to speak favourably of the plateau; it hides too much of the dinner, and is an obstacle to mutual assistance at the table, which forms in my opinion one of the pleasures of a feast instead of being a trouble: as it did among the Greeks and Romans. It is an interchange of civilities and good offices, and prolongs the repast. The drinking of healths *at* dinner, is an abomination: it is almost as bad as segars after. People who have dismissed their plate, and are at leisure, may slightly bow to each other, but to disturb a man while he is eating, and compel him to quit the plate he is enjoying, to drink when he does not wish it, is very impolite, very troublesome, and very unpleasant.

8thly. Why are the French the best bakers in Europe?

They eat more bread. The fork occupies exclusively the Englishman's left hand, the bread employs the left hand of the Frenchman, who is by no means gauche on this occasion.

9thly. In what particular has a French army an advantage over an English one?

The French are all cooks: they are better cooks: they are more frugal and saving cooks: they can manufacture an excellent meal, out of what an Englishman would waste, or throw away. In French cookery, nothing need be lost: in English cookery a fourth of the food is wasted in the cooking, or thrown away afterward from bad cooking.

10thly. Why is coin always plenty in France, and not in England?

Because their kitchens, and their sideboards require a much greater supply of the precious metals than the English. Hence the precious metals, silver especially, in use for every domestic

purpose, abound there. In England their use is *comparatively* confined to coin.

11thly. Why are the English book-binders better than the French?

The English consume more meat, or rather waste more meat than the French. They kill more calves and sheep in proportion. Hence the materials of binding are cheaper. Also, because England is superior as a grazing country.

12thly. Why do the French print books cheaper? or rather sell them cheaper?

Because the use and wear and tear of linen is much greater in France than in England; particularly at dinner. In the latter country, they use much more cotton and woollen. Our napkins and doyleys are generally, and our table cloths frequently of cotton, in America, I believe, as well as in England.

I promised to assign my reasons for not dwelling upon authorities in support of the importance of eating and drinking and the science which puts them under the guidance of health and prudence, as well as pleasure. In truth I found the materials so accumulated on my hands, that I am obliged to give up my design in compassion to my readers. After turning over Horace and Juvenal,* and the lives of Vetellius and Helio (or Ela) gabulus,

* In looking through Horace and Juvenal, I find the following articles introduced at a Roman table.

Gobeo the Gudgeon, came in the first course.

Muræna: the Lamprey, served up with Shrimp sauce. The Lamprey is not uncommon in Philadelphia, and is excellent, though neglected.

Anguilla: the Eel: a fish not much thought of: but if Elagabalus who first introduced the oyster pie, had tried an eel-pie, well seasoned, he would have found it eatable.

Rhombus: the Turbot: the first of all fish: certainly superior to the Sheep's head; when served up with lobster or shrimp sauce after the manner of the ancients. It is eaten, I understand, at Boston; which I shall note in my Gastronomic chart. I am not well acquainted with John Dory. Next to this, is

Solea: the Sole, not common here.

Passer: the Fluke or Flounder.

Mullus: the Barbel: concerning the Barbel, and the observations thereon of Plutarch and Gesner and Gasius, see Hawkin's Complete Angler, one of the most entertaining books in the language.

Silurus: the Shad. The salted Shad are peculiar to the middle states of America. I have eaten Shad in England, but not good. They do not understand relishes in England.

Scarus, the Sear.

Accipenser, the Sturgeon: the pickled Roe is the Cavear.

by Suetonius and Lampridius, I found I had to wade through the Deipnosophista of Athenæus with the commentaries of Casaubon and others, and the natural history (such as remains to us) of Aristotle, and more especially of Pliny the elder, and Galen. That I

Lupus, the Pike: a young Pike is a Jack.
Lagois, is a fish with which I am unacquainted.
Peloris, I cannot assign a modern name to.
Mytilus, a Limpen.
Murex, a Muscle: perhaps a Clam.
Cocklea, *Conchylia*, Cockles.
Echinus, a Craw fish.
Perna, a Prawn.
Squilla, the Shrimp.
Ostrea, an Oyster.
Pecten, a scollop Oyster. A Clam?

Such are the fishes mentioned in these authors: but there were many of which they take no notice.

I do not find that Horace or Juvenal mention any of the following fish, noticed by others, chiefly Pliny and Galen.

Cancer: *Gammarum*, the Crab: *Conger*, the Conger-eel: *Cyprinus*, the Carp: *Thynnus*, the Tunny: *Raia*, the Ray or Skate: *Raia clavata*, the Thornback: *Pecca*, the Pearch: *Erithinon*, *Rubellio*, the Roach: *Scomber*, the Mackarel, which ought to be far more frequent at our tables as a fresh fish, than it is. *Hilecula*, the Pilchard, the Sardini a, or the Anchovy, for I am in doubt about this. *Aurata*, the Gold fish; not the modern Chinese fish, I presume, that are now kept for ornament, but the el Dorado, so common at sea. *Xiphias*, the Sword fish. *Asellus*, the Cod. *Mustela*, *Galexia*, the Eelpout. *Glaucus*, I suspect this to be either the streaked bass, or Rock, or else the Mackarel. *Garum*, I am in doubt about this also, some think it the Mackarel, I think it was a Lobster or a Crab; it was a fish used as a pickled fish, of which the pickle was in great repute. Of the Crab or Lobster kind, I reckon the *Mæa*, and the *Echinus*. The *Lucius*, I translate a Haddock; though on the authority of Ausonius, it is usually considered a Pike. Hugo de Friedwald, supports me in this; but it is not clear. I must give up for the present the *Acus*, the *Smaris*, the *Mæna*, the *Sudis* or *Sphyræna*, the *Mollua* (soft shelled crab?) the *Lampetia*, the *Sturio*, the *Sargus* or *Melanurus*, the *Latus* (Flounder?) the *Locusta*, *Astacus* (Lobster?) the *Trachinus*, the *Cornua* or *Orphon*, the *Lamia*, the *Libella*, the *Aquila*, the *Corvus* or *Coracinus*, the *Pagrus* or *Pagyrus*, the *Clypea* or *Alosa*, with many others whereof mention is to be found in the thirty-second book of Pliny, and in Galen. It is greatly to be wished that five good scholars, including a botanist, a naturalist, and a mineralogist, would sit down to the translation of Pliny's natural history, and add notes to it. I hardly know any single man, or indeed any two men competent to the task. I do not find that the ancients knew any thing of our Trout, Salmon, or Sea Turtle. I am not clear about the Tarrapin, and the Land Turtle.

had then, to give some account of my worthy and most renowned predecessors in culinary science among the ancients, Mithæcus, who published the much-esteemed Sicilian cookery—Numenius of Heraclea—Hegeemon of Tharos—Philoxenes of Leucadia—Actides of Chio—Tyndarides of Sicyon—Thimbron of Athens—and Archistratus who went upon his Gastronomic travels, as Dr. Burney travelled to learn the modern state of music—Arthur Young that of agriculture—Ferber and Faujas that of mineralogy—Linnæus and his scholars, down to Michaud, that of botany, and so forth.

I had then to consult and analyse the cookery of Cælius Apicius, with the commentaries of Humelbergius, Caspar Barthius, Reinesius, Vander Linden, and Lister, a book of which I propose, God willing, to give a good account, the rest notwithstanding. Then had I to dive into Aldrovandus and Gesnerus *de piscibus*, among the moderns: and to dig among the ruins of the 9th folio of Gronovius for Castellanus de *carnium esu:* a dissertatiuncula de *calido potu* (which goes in Carlisle by the names of stewed whiskey, hot toddy, and potassium): and Hieronymus Mercurialis, *de potionibus ac eduliis antiquorum:* and Baccius, *de conviviis* (that is the fishing and beefstake parties) *antiquorum:* to the same pur-

Horace and Juvenal mention, *Jus*, sauce, as the same French word means: *Assis* broiled or roasted fish: roasted on a board as we do shad: also roasted meat. *Garum*, *Alec*, *Muria*, fish pickle. Garum was made from the Mackarel, as is supposed; I think from the Crab. Alec from the roe or melt of fish; the melt of our Shad, boiled for barely one minute in vinegar diluted with one third water, well spiced, is much superior to any pickled oyster. Muria, is the pickle from sea fish.

The same authors mention *Sumen*, the breast of a sow, not the udder as I think: the Hare, *Lepus*: the Boar, *Aper*: the *Pygargus*, a Roebuck? *Scythicæ volucres*, game of all kinds: *Afra*, the Turkey: *Pavo*, the Peacock, which when young is a good bird: *Turdus*, the Thrush: *Gruis*, the Crane: *Anser*, the Goose: *Merula*, the Merle: *Palumba*, the wood Pidgeon.

We learn from these authors that the ancients employed *Structor* a carver by profession; that they fined their wine with Pidgeon's eggs; that they often mixed Hymettian honey, like blockheads, even with their Falernian. They used *Mulsum* mead, as a beverage. Among their relishes (probably at the Commessatio after supper) they dipt their bread in Garum, Alec, and Muria; they had also *Hillæ*, sausages. These authors mention as vegetables in use, *Rapula*, the Rape; *Radix*, the Radish; *Lactuca*, the Lettuce; *Siser*, the Skirret; *Porrum*, the Leek. Having cast my eye with some care over Horace and Juvenal for the purpose of this essay, I thought the preceding enumeration of articles might be deemed curious at least, if of no use.

pose nearly, also is the treatise of Laurentius, *de conviviis veterum:* nor could I omit the learned remarks of Hugo Freidwall, *de sanitate tuenda*, who treats much of ancient food: Pignorius, *de servis*, or waiters at table, wherein of the sectores or carvers, very necessary to be introduced in our day; wherein Tripherius read lectures, having various dishes made in wood, dissected according to the best rules of carving: Musonii philosophi, *de luxu Græcorum, in quo de helluonibus, de bibacibus, &c.* concerning which, unless this philosopher were tolerably well skilled in the practice, he was not well qualified to write; as Harry Fielding shews at length in his history of Tom Jones. Then, had I to run over the pages of Laurentius, *de Prandio et Cæna veterum;* the blockhead thinking, I suppose, the Jentaculum, and the Commessatio, or relish after supper, of no consequence.

After this, I had to consult Meibomius, *de Cerevisiis veterum*, and Possidonius in Strabo on the smoking of cegars among the Mysian Scythæ. Strab. L. 7. ed. Casaub. Smoking and ale-drinking being naturally companions.

Nor should I have omitted the Hylophagi; or the Spermatophagi noticed by Diodorus Siculus, L. 3. ch. 7. which would of course draw after it, an investigation of the Chinese spermatology introduced to our acquaintance by Mr. Barrow, and which Sir George Staunton has strangely omitted: nor do I find that Lord Macartney himself had carefully studied it.

Nor could I have omitted the strange taste of the

"Anthropophagi who each other ate."*

Then had I to peruse the collections of Potter and Du Bos, and Kennet, and Adams: and to relieve their dull and dry details,

* The following nations have been accused of being Anthropophagi, on the authorities annexed; but I do not give full credit to all the charges.

The inhabitants of the isles of Noussa Laout near Amboyna. *Valentyn.*

The inhabitants of several islands near the isle of St. Mary. *Adams's Voyages*, 1598.

The islanders of Cayenne. *Froger's Voyages.*

The Carabees of Guadaloupe. *Voyage of Columbus.*

The tribes on the banks of the Yupara. *Condamine.* 1743.

Other Indians on the borders of the river Amazon. *Acuna and Artieda.*

Those on La Plata. *History of Paraguay.*

The savages of Brazil. *Laet Knivet.* The Mexicans and Peruvians. *Gomara. Voyage of Pizarro.*

The Scythians—Budian Scythians. *Herodotus.* The ancient Galatians. *Boemus.*

with the travels of Anacharsis and Antenor. After this I had to examine the ill natured account of an imitated ancient dinner given to us (with the relish indeed of exquisite attic salt) by the learned Dr. Smelfungus in Peregrine Pickle, to the great mortification of Akenside the poet.

When I came to consider all this, and to reflect seriously

Quid valeant humeri quid ferre recusant.

I began to despair of my undertaking, and, as the common saying is, to draw in my horns.

We have two tolerably detailed accounts of ancient dinners, that of Nasidienus by Horace, and Trimalchio by Petronius: we have two accounts excellent in their way, of the ancient dinners (or rather suppers, as they were called, though they generally began about three in the afternoon) by the Abbe Barthelemy, in the travels of Anacharsis, and by Smollet in Peregrine Pickle. To copy Horace, or Smollet, or Barthelemy, would be unpardonable: to every modern reader they are, or ought to be, familiar. But Petronius falls into few hands, nor is he an easy though an elegant author. If therefore you will accept a translation of Trimalchio's feast, and an analysis of Apicius Cælius, with some receipts in cookery out of that author, they shall be at your service.

EPICURI DE GREGE PORCUS.

The Samoydes—as their name indicates in their own language.

The Tartars of Kardan. *Voyage of Marco, polo.*

The negroes of Sierra Leona; of the Gold coast; and of the Ivory coast. *Barbot. Loyer, and Villaut.*

The negroes on the Gambia. *Le Brue.* Those of Juida. *Philips.*

Those of Dahomai, the Acquas, and Zamazones. *Snellgrave.*

The Jaggas. *Battel's Voyage.* The Mumbos of Monomatapa. *Faria,* vol. 2.

Lately the New Zealanders, and some inhabitants of the Southern isles, have been accused of the same practice. See Edinb. Ann. Reg. 1809.

See Coutumes des differens Peuples, Tom. p. 1 to 15.

NOTICES.

I HAVE received from Mr. Thomas W. Ruble, of Kentucky, notice of a steam engine of his invention, where the water of the boiler surrounds the cylinder. I suspect that although this arrangement has its conveniences, it is not new. I have heard of it in use in England.

Want of a plate prevents me from inserting Professor Cutbush's paper on Mr. Cloud's method of making seltzer water. It will appear in the next Emporium.

My publishers write to me, that complaints are made of my papers on manufactures being too long. They ask when I begin the subject of dying.

My design in this work is to make it the best publication *any where* extant, as a body of information on MANUFACTURES. I do not profess, I will not condescend to skim over my subjects with the appearance of knowledge, but with useless or shallow information, where good can be obtained. I dedicate at least one third of this work, greatly against my own inclination, to miscellaneous and comparatively trifling papers. About these I care little. But I say to those who complain,

Shew me in any European language, the same amount of real information, on *Iron*, *Steel*, *Steam Engines*, *Copper*, and *Lead* in the same brief compass as I have given it.

Shew me, any single European publication on either of these subjects, that contains any thing approaching to the same quantity of important knowledge, which the Emporium has furnished.

I say to those who complain, that *they cannot shew this.* I know it.

Under these circumstances, if the work be such as I represent it (and if it be not, let those who can shew otherwise)—if it really do contain a condensed body of manufacturing information, not to be found but by hunting up publications scarce, voluminous, and dear, and not then—what reason have I to change my plan, or to suspect that such a work will not be reasonably supported? If it be not, it is well: I will give it up: but I will not swerve from my own ideas of propriety in conducting it.

As to dyeing, I suppose there may be twenty or thirty subscribers anxious for such an article, and caring nothing about any other part of the work: I believe the articles I have published, of far more importance; but it shall have its turn. T. C.

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LEAD.

In treating of the article lead, the following notices respecting the manufacture of SHOT escaped me.

Granulation of Shot.

The manufacture of common flowling shot consists merely in causing the fused metal to fall in equal spherical drops into water. The lead is melted with the addition of a small proportion of arsenic, which, being reduced to a metallic state, by means of grease stirred in during the fusion, renders it less fluid. An oblong shallow vessel of iron, perhaps 10 inches wide, 14 long, and 2 1-2 deep, called a *card*, whose bottom is pierced with holes proportionate to the intended size of the shot, is placed at the height of from one to three inches, over the surface of a tub of water, covered with a thin film of oil. The card is previously heated to the temperature of the metal by immerging it in the cauldron; and a stratum of soft dross or scoriæ, which are found on the surface of the fused alloy, is then placed on its perforated bottom, and, being slightly pressed down with the ladle, forms a

kind of filter, which partly chokes up the apertures, and prevents the metal from flowing through them in continuous streams. The fused metal is then poured by ladlefulls into this vessel, and appears notwithstanding to run through it with considerable velocity; so that it seems difficult to believe that it falls in separate drops, till convinced by taking up a quantity of shot, from the bottom of the water.

The shot thus made is not without considerable imperfections. The exterior coat of the lower part of the drop becoming suddenly fixed by the contact of the water, its superior portion, which is still liquid, as it also cools and contracts, necessarily pits, like the surface of metal in the channel of a mould, so that the greater part of the shot are somewhat hollow and of an irregular form; consequently too light for the purpose to which they are destined, and liable to unequal resistance in their passage through the air. These defects are remedied in the patent shot, the manufacture of which differs only from that of the preceding kind in the addition of a larger portion of arsenic, which varies according to the quality of the lead; *in dropping it from such a height that it becomes solid before it enters the water*, which is from 40 to 100 feet; and in some subsequent operations, which are as follows: It is first dried and sifted. It is then *boarded*, which consists in scattering it on several polished slabs or trays of hard wood, with rims, in the form of a II, except that the sides converge towards the lower part, to which a slight inclination and alternate motion in their own planes are given by boys employed in the manufacture. The shot whose form is imperfect are detected by the sluggishness of their motion, and remain behind, whilst the others roll off from the board. The last operation is the polishing; which is performed by agitating it, with the addition of a very small quantity of black lead, not exceeding two

spoonfuls to a ton, in an iron vessel, turning on an horizontal axis, like a barrel-churn. It does not appear that any higher degree of perfection than that which is thus attained remains to be desired. The argentine brilliancy of the shot when newly made, the beautiful accuracy of its form, and the curious instance of inanimate tactics which it presents when scattered on a plate, render it even an agreeable object of contemplation.

Rifled Shot.

In the latter end of the year 1789, I was, by various considerations, induced to think, that the effect which is produced by rifling musquetry might be produced in artillery by giving a suitable figure to the shot. It is almost needless to explain this effect. When a bullet is driven along the bore of a piece, it must be acted upon by the internal surface so as to cause a rotation, the axis of which motion will lie across the line of direction. In consequence of this, the re-action of the air will be stronger on one side of the bullet than on the other, and it will deviate from the intended course according to no certain rule. The method of rifling consists in cutting one or more spiral grooves in the hollow surface of the musquet, into which the ball is either forcibly rammed down, or else conveyed to its place by an aperture at the breach, or near the chamber. The lead is thus made to fit the internal screw, and usually takes about half a turn during its course through the barrel. The axis of this rotation being parallel to the line of direction, it must follow that the resistance of the air will be equal on all sides of the bullet, and it will fly with more certainty to the object of aim. It seemed to me, that if a cylindrical shot, with hemispherical ends, were thrown out of a common barrel, it might be possible, by means of certain spirals cut

on the end surface, to cause the blast of the powder and the resistance of the air to concur in producing the same rotation.

For this purpose I took a wooden pattern, and cut the spherical surface into twelve spiral planes, by dividing the equator into the like number of equal parts, and drawing spirals from the points of division obliquely towards the poles. The wood between every pair of contiguous spirals was then taken away, by cutting from the one line parallel to the axis, and from the other perpendicular to a plane passing through it. By this process, when the axis was set upright, there appeared, as it were, twelve roads sloping upwards from the equator towards the pole, bounded on the side next the wood by upright walls; and the shot, when suspended on an axis or centre point, could be blown round very swiftly by the breath directed towards the pole.

Shot of this kind were made and tried at a foundery in North Wales. By an experiment with a brass gun newly bored, it was ascertained that the shot did really revolve in its course along the bore; but the trials with shot of different weight and dimensions did not promise more accuracy of effect than was obtained by common spherical shot used at the same time. Particular notice was taken of the manner in which the shot struck the butt: the greatest number of times, it struck with the anterior end; sometimes the stroke was made with the broad side, and, in a few instances, the end which came last out of the gun arrived first at the mark. Hence it appears, that the very slight angular deviation at the mouth of the piece is more than sufficient to counteract any effect which might else have been derived from the subsequent action of the air upon a projectile duly figured.

It seems, nevertheless, that this principle might be applied to advantage in bar shot. If the ends of this pro-

jectile were chamfered or sloped with respect to the axis, it would pass through the air with a revolution of its extremities, instead of one end following the path of the other, as may sometimes be supposed to happen.

With regard to the execrable practice of war, I think it a decided question, that increase of power is, on the whole, in favour of rectitude and virtue; and that wars are likely to be fewer, less durable, and less pernicious, the more scientifically they are conducted.

[1 *Nich.* 267—383. *quto.*

Sugar of Lead.

The following process for making this article, I translate from the account given by M. de Machy in the second part of the 6th vol. of the Encyclopedie, Arts et Metiers p. 758.

Into a stoneware jar of sufficient capacity put 25lb. of white lead, or of litharge; (the common white lead adulterated with whiting will not well answer the purpose. T. C.) and about 15 gallons of distilled vinegar. Place it in a warm situation which may be near to the furnace wherein the vinegar is distilled. Let it remain in this situation, till the vinegar is saturated, and has acquired a full sweet taste: it must be stirred every now and then with a long stick. When it has stood a sufficient time to be quite clear, lade off the clear liquor by means of leaden or wooden vessels, into a leaden boiler, fixed in a frame of brickwork. Light under it a moderate fire, and evaporate the liquor gently, till a drop when cold becomes solid.

Then transfer it into small glazed earthen pots of a square shape, about the size of a half hundred weight, having a hole near the bottom stopped with a wooden stopper. On the top of the pots pour about four ounces of spirit of wine, which forms a kind of border or cover-

ing that prevents the evaporation of the moisture. Keep these pots in a warm place till they are full of crystals. Then draw the stopper, let the liquid part run out, and collect the crystals. The liquor that is drawn off will be thick, and too much loaded with lead. It must be diluted with distilled vinegar, filtered, and again set in a warm place to evaporate, and crystallize.

I believe the preceding process would be improved, by adding one sixth part of good distilled vinegar to the first clear liquor. T. C.

The method of making sugar of lead as detailed by M. Pontier in the 37th vol. of the Annales de Chimie, p. 272, is in substance as follows. The vessels are casks, iron-hooped, with wooden cocks; a copper still with a tin alonge (long tube adapted) or worm, and with a cock to let out the sediment; stoneware jars to hold the vinegar; a cast-iron pot to melt the lead in; stoneware jars also, to hold the vinegar and lead; copper boilers tinned the same size of the still; half a dozen or more wooden filters.

Cast the lead in very thin sheets, as the plumbers do; milled lead will not answer so well; cut it in pieces indiscriminately; put them in the vinegar distilled in your still, in the stoneware jars; the vinegar should be strong; do not close the jars, it is sufficient to cover them from dust; change the oxyded lead two or three times a day, putting it in the place of the lead submerged; boil the vinegar with the white lead in it, in the tinned copper boilers, to finish the saturation; (I think this can be done by putting the jars themselves with their contents in a bath of boiling water, T. C.) Filter the liquor; evaporate to a pellicle; (I think a sixth of distilled vinegar should be added, previous to evaporation, T. C.) dry the crystals in the shade. The residuum may be treated in the same way, but it does not give so clear crystals as at the first solution.

TIN.

I do not know that any specimen of this very useful metal, has yet been found in the United States. To facilitate the search after it, I shall state its geological, as well as mineralogical characters. This metal and antimony, being the only two metals of which we stand in need, that are furnished principally by Great Britain, I shall be excused, I hope, for dwelling upon it more than otherwise would be necessary.

Tin is found, 1st. native; a scarce form of appearance. 2ly, Sulphuretted; tin pyrites. 3ly, As an oxyd, the common Cornish ore. Tin Stone.

Werner's account of the age of metals, I shall insert at the end of this article.

The first part of this article, relating to the ores of Tin, I take from Jamieson; the next from Aikin; the chief part of the remainder from Watson, Bishop of Landaff.

TIN GENUS.

FIRST SPECIES.

Tin-Pyrites. Sulphuret of Tin.

Zinnkies.—*Werner.*

Id. Wid. s. 875.—Tin Pyrites, *Kirw.* vol. ii. p. 200.—Zinnkies, *Emm.* 2. b. s. 418.—Etaine sulphure, *Lam.* t. 1. p. 279.—*Id. Hauy*, t. 4. p. 154.—La Pyrite d'Etain, ou l'Etain pyriteux. *Broch.* t. 2. p. 332.—Zinnkies, *Reuss*, 4. b. s. 286.

External Characters.

Colour intermediate between steel-grey and brass-yellow, but usually more inclined to the first.

Occurs massive and disseminated.

Internally it is glistening, sometimes shining, and seldom passes into splendent, and its lustre is metallic.

Fracture sometimes small and coarse grained uneven; sometimes, but rarely, inclining to small and imperfect conchoidal, and imperfect foliated.

Fragments indeterminately angular, blunt-edged.

Is semihard, passing into soft.

Brittle.

Easily frangible.

Heavy.

Specific gravity, 4.350, *Klaproth*; 4.785, *La Metherie*.

Chemical Characters.

Before the blow-pipe it gives a sulphureous odour, and melts easily, without being reduced, into a black scoria.

It communicates a yellow or green colour to borax.

Constituent Parts.

Tin	34
Copper,	36
Iron,	3
Sulphur,	35
Earthy matter,	2
Klaproth.	100

Geognostic and Geographic situations.

It has been hitherto found only at Wheal-rock and St. Agnes in Cornwall, where it occurs in a vein about nine feet wide, accompanied with copper-pyrites and brown-blende, or sulphuret of zinc.

Observation.

It was formerly confounded with Magnetic Pyrites.

SECOND SPECIES.

Tin-Stone.

Zinnstein.—*Werner.*

Stannum Arsenico et Ferro mineralisatum, *Wall.* t. 2. p. 319. et seq.—Zinnstein, *Werner*, Pabst. 1. b. s. 171.—*Id. Wid.* s. 880.—Common Tin-stone, *Kirw.* vol. ii. p. 197.—Etain vitreux, *De Born.* t. 2. p. 238.—Zinnkeis, *Emm.* b. 2. s. 420. Oxide d'Etain, *Lam.* t. 1. p. 274.—Etain oxide, *Hauy*, t. 4. p. 137.—La Pierre d'Etain, ou la Mine d'Etain commune, *Broch*, t. 2. p. 334.—Zinnstein, *Reuss*, 4. b s. 288.

External Characters.

Its most common colour is blackish-brown; from which it passes, on the one side, into brownish-black and velvet-black; on the other side, into hair-brown and reddish-brown, from which it passes further into yellowish-green, yellowish-white, and greenish-white.

Occurs massive, disseminated, in rolled pieces, in grains as sand; but most frequently crystallized, and the crystals, which are four sided prisms, are in general very indistinct.

The surface of the crystals is usually smooth, seldom more or less strongly streaked, and it is commonly splendent.

Internally it is only shining and glistening, and its lustre is intermediate between resinous and adamantine, but more inclining to the latter.

Fracture coarse and small-grained uneven, inclining to imperfect conchoidal; seldom imperfect foliated, and extremely seldom perfect foliated, and then it is highly splendent.

Fragments indeterminately angular, pretty blunt-edged.

The massive varieties occur commonly in coarse, small and fine granular distinct concretions.

It alternates from semitransparent to opaque; the darker coloured varieties are opaque, the lighter translucent and semitransparent, often even inclining to transparent; the intermediate varieties are only translucent and translucent on the edges.

Yields a greyish-white streak.

Is hard, but does not give fire with steel.

Easily frangible.

Specific gravity, 6 to 7.

Chemical Characters.

Before the blow-pipe, it decrepitates, becomes paler, and where it rests on the charcoal is reduced. When roasted, it is converted into a grey oxyde. Acids dissolve the iron it contains, but only a very minute portion of the tin.

Constituent Parts.

From Alternon.		Schlakenwald.	Ehrenfriedersdorf.
Tin,	77.50	75.0	68
Iron,	0.25	0.50	9
Oxygen,	21.50	24.50	16
Silica,	0.75		7
	100	100	100
	Klaproth.	*Klaproth.*	*Lampadius.*

Geognostic Situation.

In occurs only in *primitive rocks*, as granite, gneiss, mica-slate and clay-slate, and is the oldest of all the metals. It occurs either disseminated in the rock, or in *stockworks*, beds, or veins. It is usually accompanied with quartz, mica, lithomarge, steatite, wolfram, tungsten, arsenic-pyrites, copper-pyrites, iron-pyrites, molybdena,

black and brown blende; less frequently with fluor-spar, topaz, appatite, felspar, schorl, magnetic ironstone, copper-glance, lead-glance, and white lead ore. It is found also in great quantity in *alluvial* land. The greater part of the English, much of the Spanish, and the greater proportion of that in India, occurs in that situation.

Geographic Situation.

Tin is not found in many countries, but where it does occur, it is in very considerable quantity. In the most northern countries it is entirely wanting. In *Europe* there is only three tin districts. The first is in the Erzgebirge, on the Saxon and Bohemia sides, and extends as far as the Riesengebirge and Fichtelgebirge. The second district is in Cornwall. The third is that of Galicia on the borders of Portugal.

In *Asia* it is found, in vast quantity, in the peninsula of Malacca, Siam, and in the island of Banka.

In *America* it is said to occur near Cochimbo, and in Chili.

Use.

It is worked as an ore of tin, and from it all the tin of commerce is obtained.

Observations.

1. Its name is derived from the great quantity of tin which it affords, and its unmetallic-like aspect.

2. It is distinguished from *Wolfram* by its inferior hardness, as it does not give fire with steel; and by the streak, which in tinstone is greyish-white, but in wolfram reddish-brown: from *Blende* by its inferior hardness and uneven fracture.

THIRD SPECIES.

Cornish Tin-Ore, or Wood-Tin.

Kornisch Zinnerz.—*Werner.*

Mine d'Etain mamelonnee, ou en Stalactites, *Rom. de L.* t. 3. p. 428.—Kornisch Zinnerz, *Werner*, Pabst. 1. b. s. 183.—*Id. Wid.* s. 877.—Wood Tin-Oore, *Kirw.* vol. ii. p. 198.—Etain limoneux, *De Born.* t. 2. p. 248.—Kornisch Zinnerz, *Emm.* 2. b. s. 427.—Mine d'Etain ferrugineuse, *Lam.* t. 1. p. 281.—Etain oxide concretionne, *Hauy*, t. 4. p. 147.—La Mine d'Etain grenue, ou l'Etain grenu, *Broch.* t. 2. p. 340.—Holzzinnerz, *Reuss*, p. 4. s. 300.

External Characters.

Its most common colour is hair-brown, of different degrees of intensity, which passes into wood-brown, and nearly into yellowish-grey, sometimes into reddish-brown. In single pieces it is sometimes striped.

Occurs usually in rolled pieces; sometimes we can observe its original shape, which appears to be small reniform; and with impressions.

The kidney-shaped or reniform is black on the surface, and bears a considerable resemblance to hematite.

Externally glistening.

Internally it is glistening and glimmering, and its lustre is resinous, inclining to adamantine.

Its fracture is delicate, straight, scopiform and stellular diverging fibrous.

Fragments wedge-shaped and splintery.

It occurs usually in large and coarse granular distinct concretions, which are intersected by curved and thin lamellar concretions, and the colour delineation is in the direction of the latter.

The streak is shining and yellowish-brown.

Is opaque.

Hard.
Brittle.
Easily frangible.
Uncommonly heavy.
Specific gravity, 5.800 *Brunnich;* 6.450 *Klaproth.*

Chemical Characters.

Before the blow-pipe, it becomes brownish-black, but is infusible or irreducible, either alone or with borax. In a charcoal crucible, *Klaproth* obtained 0.6333 of tin. It is little affected by acids.

Constituent Parts.

Klaproth found it to contain in the hundred parts, 63 parts of tin, with iron and arsenic.

Geognostic and Geographic Situations.

Has been hitherto found only in Cornwall, and there in alluvial land, accompanied with tinstone.

Observations.

It bears a strong resemblance to Brown Hematite; from which, however, it is distinguished by its hair-brown colour, its rolled pieces, greater hardness, and higher specific gravity. [*Jameson's Mineralogy.*

Ores of Tin.——Aikin.

The existence of native tin was long a matter of doubt among mineralogists. It has, nevertheless, been undoubtedly found in various places. Magellan, among other specimens, mentions, 1. Malleable tin in a granular form, and also foliaceous, bedded in a white hard matter, resembling quartz, but which, on proper examination, proved to be arsenic; a circumstance that evinces its being native tin, because the arsenic could not have retained this form, if the tin had undergone the fusing heat.

It appeared like a thick jagged or scolloped lace or edging, and was found at St. Austel in Cornwall, England. 2. In the form of crystalline metallic laminæ, or flat crystals, rising side by side out of an edging, which shone like melted tin. They were nearly as thin as the leaves of talc, intersecting each other in various directions, with some cavities between them, within which appeared many specks and granules of tin that could easily be cut with a knife; this also came from Cornwall. 3. In a massy form, more than an inch thick in some places, and enclosed in a stone resembling quartz, which was taken to be a hard crust of crystallized arsenic.

All the ores of tin hitherto found, except the sulphuret from Huel or Wheal Rock, St. Agnes, Cornwall, are in the oxided state. They are remarkable for their great weight, which is between 5.8 and 6.97, according to Klaproth.

The common ore, called tin-stone, has a vitrified appearance, resembling a garnet of a blackish-brown colour, but much heavier. Its surface is shining, sometimes striated, and its fracture lamellar; soft enough to be cut or scraped with a knife, and affording a pale red powder. Some authors assert, that it contains arsenic, but Kirwan positively denies the existence of arsenic as a mineralizer of tin. The Germans call the irregular compact tin ore by the name of zinnstein; but the crystallized tin-stones are called zinngraupen, if the crystals be distinct and somewhat large. The zinnzwitter ores, in which the crystals are small, and not so distinct, resemble small grains, scattered through a compact raw tin-stone, or a stone of any other kind.

The common matrix of tin in the Cornish mines is the killas, and the growan. This consists of white clay, mixed with mica and quartz, without any particular texture; which, when lamellar and hard, is called gneiss by the

Germans, and is nothing else but decayed granite, in which the feltspar has been broken down to clay.

The zinngraupen, or brown crystallized tin-stone, from Cornwall, consists of quadrangular prisms, or double quadrangular pyramids, joined by their bases, so that these crystals are octoedral; these are found at Trwaunance and Soil-hole, in the parish of St. Agnes. Similar prismatic crystals, but of as small a size as a hair, are found in tin-stone upon killas, at Polgooth, one of the richest tin mines, which produces sometimes a clear profit from 100 to 1200*l.* sterling per month.

The stream-tin is collected in the vallies of the tin mountains in Cornwall, and yields a considerable quantity of this metal. The soil is dug several feet deep, and washed by water going over it, till the heavier particles of the ore remain at the bottom. These are nothing else but the abrasions of the tin ores over the mountains, which are rolled down the declivities of the hills to lower grounds.

The stream-tin from Pensagillis is remarkable on account of the native gold now and then met with in it; and found, though very rarely, in pieces of the value of two or three pounds sterling. It principally consists of round, oval, and somewhat smooth pieces, from the size of a bean to that of a pea, and less, the polished surfaces of which show a variety of reddish, gray, light-brown, and dark yellow colours.

The wood-tin ore looks like hematites, and is found in the parishes of St. Columb, Roach, and St. Denis. This is without any crystallized form, and has a very inconsiderable quantity of iron with it.

Another wood-like tin ore, described by professor Brunnich, shows various fine fibres converging to different centres, like a radiated zeolyte; but is so compact and hard, as to strike fire with steel. Its specific gravity,

at 45° of Fahrenheit, is 5.80, and even 6.45. It contains some arsenic and a considerable portion of iron; and gives sometimes 63.5 per cent. of tin. It is very scarce, and found only in small pieces.

The tin spar, or white tin ore, is generally of a whitish or gray colour; sometimes it is yellowish, semitransparent, and crystallized, either of a pyramidal form, or irregular. It resembles a calcareous, or rather ponderous spar, but is easily known by its great weight, and shining greasy appearance. Its fracture also is vitreous. It was formerly thought to contain arsenic, but Margraaf found it to be the purest of tin ores; though it is said to contain sometimes a mixture of calcareous earth. Its specific gravity is=6.[illegible]07.

The grains are of a spherical polygonal figure, like the garnets; but seem more unctuous on their surface. It is found either in large or small grains.

Bergman received a specimen of native aurum musivum from Nerschinskoi in Siberia. It resembled the artificial aurum musivum externally, or rather the aurum musivum formed a crust environing a nucleus radiated in its fracture, and resembling a white metal. It yielded to the knife, and the place of section exhibited a variable colour. Its powder was black. By the analysis, it proved to consist of tin mineralized by sulphur, with a very small portion of copper. In the Journal de Physique for 1783, it is said, that the specimen was too small to admit of a determination of the quantities in the large way: but in the preface to the Sciagraphia it is said, that the native aurum musivum contained forty parts of sulphur to one of tin: and the other mineral, which resembled antimony, contained one fifth part of sulphur only.

At Huel Rock, in St. Agnes, in Cornwall, there has been found a metallic vein nine feet wide, at twenty yards beneath the surface. Raspe was the first who discover-

ed this to be a sulphuret of tin: it is very compact, of a blueish white colour, approaching to gray steel, and similar to the colour of gray copper ore: it is lamellar in its texture, and very brittle. It consists of sulphur, tin, copper and some iron. Raspe proposes to call it bell-metal ore.

According to Klaproth's analysis of this ore, 100 parts contain 25 of pure sulphur, 34 of tin, 36 of copper, 2 of iron, and three grains of the stony matrix. A faint smell of arsenic was perceptible in roasting it. The darker varieties, however, are much poorer in tin, and contain more iron.

Bergman's method of assaying tin ores in the humid way is too commonly ineffectual. Klaproth gives the following mode. Mix the ore, in fine powder, with a lixivium containing six times its weight of caustic potash; evaporate to dryness, in a silver vessel, on a sand heat; and then keep in a state of moderate ignition for half an hour. Dilute the mass, while yet warm, with boiling water, and filter. Let the residuum be again ignited with six times its weight of potash, and dissolve in boiling water, as before. Mix the solutions, and add muriatic acid, till the precipitate, which falls down, is dissolved by its excess. Separate the tin from the acid by carbonat of soda; wash the precipitate; dry it; and redissolve it in muriatic acid by a gentle heat. Into the colourless solution, diluted with two or three parts of water, put a stick of zinc, and in a few days the whole of the tin will gather round it in dendritic laminæ. The residuum left after the second solution is to be treated with muriatic acid, and what tin is in it precipitated by zinc in the same manner. If it contain any iron, this may now be precipitated by prussiat of potash.

The sulphuret requires to be treated somewhat differently. To one part of the powdered ore add four of mu-

riatic, and two of nitric acid, and after they have stood together 24 hours, digest for some time in a gentle sand heat; then dilute with a little water, and filter. Let the sulphur of the residuum be burned off on a test, and treat what remains with fresh nitro-muriatic acid. The part not soluble being ignited with a little wax, the iron will be reduced, and the remainder is silex from the matrix. The solutions are to be precipitated with carbonat of potash; the precipitate redissolved in muriatic acid diluted with three parts of water; and a stick of pure tin immersed in this solution. The copper will be deposited on the tin, and leave the solution colourless. The copper being dissolved by brisk digestion in nitric acid, if any tin be mixed with it, this will fall down in the state of white oxyde. The tin may be separated by zinc, as in the preceding instance; and what was dissolved from the stick used in precipitating the copper, must be deducted from its weight.

In the dry way, these ores, after pulverization and separation of the stony matter by washing, are to be melted with a mixture of double their weight of a flux, consisting of equal parts of pitch and calcined borax, in a crucible lined with charcoal, and to which a cover is luted; fusion should be speedily procured.

Bergman recommends a mixture of one part of the ore with two of tartar, one of black flux, and half a part of resin:* this is to be divided into three parts, and each successively projected into a crucible heated white, and immediately covered after the foregoing portion ceases to flame; the whole operation takes up but seven minutes, or less.

Previous to smelting in the large way, the impure ores of tin must be cleansed as much as is possible from all heterogeneous matters. This cleansing is more necessary in ores of tin than of any other metal, because in the

* The tartar and black flux are bad. T. C.

smelting of tin ores a less intense heat must be given, than is sufficient for the scorification of earthy matters, lest the tin be oxyded. Tin ores previously bruised, may be cleansed by washing, for which operation their great weight and hardness render them well adapted. If they be intermixed with very hard stones, or ferruginous ores, a slight roasting will render these impure matters more friable, and, consequently, fitter to be separated from the tin ores. Sometimes these operations, the roasting, contusion, and lotion, must be repeated. By roasting, the ferruginous particles are so far revived, that they may be separated by magnets.

The ore, thus cleansed from adhering heterogeneous matters, is to be roasted in an oven, or reverberatory furnace, with a fire rather intense than long continued, during which it must be frequently stirred to prevent its fusion. By this operation the arsenic is expelled, and in some works is collected in chambers built purposely above the oxyding furnace.

Lastly, the ore cleansed and washed is to be fused, and reduced to a metallic state. In this fusion, attention must be given to the following particulars:

1. No more heat is to be applied than is sufficient for the reduction of the ore, because this metal is fusible with very little heat, and is very easily oxydable.

2. To prevent this oxydation of the reduced metal, a larger quantity of charcoal is used in this than in the other fusion.

3. The scoria must be frequently removed, lest some of the tin should be involved in it; and the melted ore must be covered with charcoal powder, to prevent the oxydation of its surface.

4. No flux or other substance, excepting the scoria of former smeltings which contains some tin, are to be added, to facilitate the fusion.

The above methods of assaying tin ore, by means of the fixt alkalies, is due to Klaproth: but the following method in the dry way, appears to me sufficient for most purposes, and less complicated.

Pound the ore; separate it from the stony matters that accompany it; take a piece the size of a pepper corn, and roast it on charcoal with the blow pipe; if any sulphureous or arsenical fumes should arise on this trial, the pounded ore must be well roasted previous to fusion, with a little charcoal; if no such vapours appear, the roasting may be dispensed with. Take 400 grains of the ore; smear the sides of a crucible with charcoal, and put a small quantity of charcoal dust in the bottom; mix up your pulverized ore with pitch and sawdust; lute a cover on your crucible; urge it with a fire quickly raised, during fifteen minutes in an air furnace or blacksmith's forge.

The method of treating the ores of tin in Cornwall, England, is two-fold. The first that we shall mention, is that to which the tin-stone from the mines or vein-tin is subjected; the second is that by which the stream tin is reduced.

1. The vein-tin is procured by blasting, and when brought to the top of the pit, is in fragments of various sizes, and mixed so largely with quartz, argillaceous schistus, granite, and other impurities as rarely to contain more than 2 per cent. of metal. The first preparation that it receives, is being broken by hand hammers, about the size of hens' eggs, after which it is ready to be stamped. The stamping-mill is of the usual construction, except that the stampers are only three in number, and in front of the trough or coffer, there is inserted a plate of tin about a foot square, pierced full of holes, large enough to admit a moderate sized knitting-needle; that surface of the plates which is occupied by the rough extremities of

the holes, is placed on the inside of the trough, by which simple and effectual contrivance, the holes are prevented from being plugged up by the ore. In proportion as the tin-stone is reduced to the proper degree of fineness, it passes with the water through these holes into a labyrinth, of very simple construction; here the oxyd of tin is separated from much of the lighter impurities, and by subsequent washing on a wooden table, it is sufficiently dressed to be sent to the roasting furnace; in this state it is called black tin, and is generally mixed in considerable proportion with mispickel, and iron and copper pyrites.

It is now calcined at a low red-heat in a large reverberatory furnace for several hours, in order to volatilize the arsenic and burn off the sulphur, (a part of this last after being acidified, combines with the oxyds of copper and iron.) The ore comes out of the roasting furnace, of a bright ochery red colour, owing to the decomposition and oxydation of the pyrites and mispickel, the oxyd of tin, if the operation has been well performed having undergone not the least alteration. The ore is now washed a second time, by which nearly the whole of the impurities are separated. The water employed in this process, being considerably impregnated with sulphat of copper is reserved, and afterwards decomposed, by the addition of pieces of old iron. The next step is the reduction, properly speaking; for this purpose a reverberatory furnace, about seven feet long and three and a half feet wide, is charged with seven hundred cwt. of roasted ore mixed with one-fifth of its bulk of culm (Welch small coal)* no lime or any other kind of flux being made use of; the fire is kept up pretty brisk for about six hours, and the tin in proportion as it is reduced, sinks down to the bed of the furnace, being covered with a boiling hot bath of black scoriæ.

* Giving no smoke. T. C.

At the expiration of this period, the furnace is tapped by means of an iron bar, and the hot metal flows into a shallow pit at the foot of the furnace. When the whole of the metal has run out, the scoriæ are drawn out of the furnace with a rake, and a fresh charge is immediately thrown in. While the metal in the pit is red-hot, it throws up a quantity of slag very rich in metal, which is immediately returned into the furnace, and the melted tin after it has become sufficiently cool, is taken out with iron ladles and poured into moulds of granite, where it consolidates; each charge, affording on an average, from four to five hundred weight of metal. The first scoriæ are not entirely exhausted of metal, and are therefore transferred to the stamp-mill, and afterwards washed, in order to separate the richer particles, which are then mixed with the next parcel of roasted ore.

The pigs of tin thus procured, are next put without any addition, into a small reverberatory furnace, where they are exposed to a very gentle heat, the purest part of the tin first melts as it is drawn off, forming the common grain tin; the more refractory part containing a small but variable portion of copper, arsenic, and iron, is then brought to a state of fusion, and cast into pigs, forming the common or ordinary tin.

2. The stream tin-stone is not, we believe, found in any other part of Europe, than Cornwall, (Eng.) It differs from the former in its extreme purity, and absolute freedom from arsenic, and in its occurring in alluvial beds. The largest stream-tin work is at Carn, about two miles to the S. E. of Perran, not far from Redruth. It is situated in a valley, through which flows a stream, the course of which has been turned, for the sake of getting at the treasure concealed beneath its bed. The workmen first dig through a stratum about fifty feet thick of clay, shells and black earth, in which has been found hazel nuts, the

antlers of an animal of the stag kind, a human scull, and a copper battle-axe; to this succeeds a layer of rounded stones, beneath which is the bed of tin ore, in grains and lumps of various sizes. The thickness of this bed varies from one to five feet, but the thickest part is comparatively the poorest. The whole of the superincumbent strata is cut away, as the workmen proceed, so that the general appearance of the cavity is that of a vast gravel or sand pit, near half a mile long, and about two hundred feet broad, which is kept clear of water by the powerful action of two water-mill pumps. The tin ore, as it lies quite loose, is merely shovelled into barrows, and wheeled to the head of the works, where it is thrown under a thin sheet of water which washes away the earth, leaving the pure ore behind. After this simple purification the ore is sent to St. Austle, a distance of about twenty miles, to be smelted. Here all the preparation for the furnace, that it receives is being bruised and passed through wire sieves, containing sixteen meshes in the square inch. The furnace employed is called in Cornwall, England, a blowing furnace, and is in fact only a blast furnace of the simplest construction, about seven feet high, and supplied with air from two cylinders, worked by an overshot water-wheel. The only fuel made use of is charcoal, and after the furnace is fully heated, it is fed at short intervals with the following charge, viz. three or four shovels-full of ore, and two or three half-bushels of charcoal, no flux of any kind being employed. At the bottom of the furnace is a small channel, through which the reduced tin is constantly flowing into a pit below, accompanied by a small quantity of slag, which is removed from time to time, and thrown again into the furnace. When the pit is full of tin, it is ladled out into an iron boiler, about three feet in diameter, with a small fire under it, to keep the metal sufficiently fluid: two or three large pieces of charcoal are then laid

upon the tin, and plunged to the bottom by means of an iron instrument resembling a wheel, with a long handle fixed in the axle. A violent ebullition is immediately excited, and a little slag, which was before mixed with the metal, rises to its surface, and is scummed off. In a minute or two after, the metal is tried, by taking up a ladleful and pouring again into the mass, when if it appears quite bright like silver, and of an uniform consistence, the purification is complete, and nothing more is requisite than to cool it to a proper degree, and lade it into the moulds, by which it is formed into pigs, weighing from two to three hundred weight each. If the metal is poured too hot into the moulds, it is apt to be brittle. Good stream-tin affords from 65 to 75 per cent. of the very best and purest grain tin.

None of the Cornish tin may be sold till it has been coined; for this purpose a small piece is cut off from every pig and assyed; if it appears of the requisite purity, it receives the stamp of the Duchy, and pays to the Prince of Wales, as Duke, four shillings per cwt.

Tin is a metal of a yellowish white colour, considerably harder than lead, scarcely at all sonorous, very malleable, though not very tenacious. Wires cannot be made of it; but under the hammer it is extended into the leaves, called tin foil, which are about one thousandth of an inch thick, and might easily be beaten to less than half that thickness, if the purposes of trade required it. *Aikin.*

The following remarks of the Bishop of Landaff, on Tin, on the alloys of Tin, and on the tinning of copper vessels, are very instructive.

" Tin ore, though it is sometimes unmixed, is often otherwise; it frequently contains both tin, and iron, and copper. The fire with which tin ore is smelted, is sufficiently strong to smelt the ores or the other metals which

are mixed with it; and hence the reader may understand, that, without any fraudulent proceeding in the tin smelter, there may be a variety in the purity of tin, which is exposed to sale in the same country; and this variety is still more likely to take place, in specimens of tin from different countries, as from the *East Indies*, from *England*, and from *Germany*. This natural variety in the purity of tin, though sufficiently discernible, is far less than that which is fraudulently introduced. Tin is above five times as dear as lead; and as a mixture consisting of a large portion of tin with a small one of lead, cannot easily be distinguished from a mass of pure tin; the temptation to adulterate tin is great, and the fear of detection small. In *Cornwall*, the purity of tin is ascertained, before it is exposed to sale, by what is called its *coinage*: the tin, when smelted from the ore, is poured into quadrangular moulds of stone, containing about 320 pounds weight of metal, which, when hardened, is called a *block* of tin; each block of tin is coined in the following manner:—"the officers appointed by the duke of Cornwall, assay it, by taking off a piece of one of the under corners of the block, partly by cutting and partly by breaking; and if well purified they stamp the face of the block with the impression of the seal of the Duchy, which stamp is a permisssion for the owner to sell, and at the same time an assurance that the tin so marked has been purposely examined, and found merchantable*." This rude mode of assay, is not wholly improper, for if the tin be mixed with lead, the lead will by its superior weight sink to the bottom,† and thus be liable to be discovered, when the bottom corner of the block is examined. But though the seal of the Duchy may be some security to the original purchasers of block tin, it can be none at all to those foreigners who purchase

* Borlase's Nat. Hist. of Corn. p. 183.

† I doubt this. T. C.

our tin from *Holland;* for, if we may believe an author of great note,—“in Holland every tin founder has English stamps, and whatever his tin be, the inscription, block tin, makes it pass for English*.” This foreign adulteration of English tin may be the reason that *Musschenbroeck*, who was many years professor of natural philosophy at Utrecht, puts the specific gravity of what he calls *pure tin* equal to 7320, but that of English tin, and he has been followed by *Wallerius*, equal to 7471†; for it will appear presently, that such sort of tin must have contained near one tenth of its weight of lead.

Weight of a cubic foot of English tin, according to different authors.

Cotes, Ferguson, Emerson	7320 oz. avoir.
Boerhaave's Chem. by Shaw	7321
Musschenbroeck and Wallerius	7471
Martin	7550

From the following experiments it may appear probable, that not one of these authors, in estimating the specific gravity of tin, has used the purest sort, but rather a mixture of that with lead, or some other metal.

A block of tin, when it is heated till it is near melting, or after being melted, and before it becomes quite fixed, is so brittle that it may be shattered into a great many long

* Newman's Chem. by Lewis, p. 89.

† Musschen. Ess. de Phys. 1739. French Trans. Wallerii Min. Vol. l. p. 154. There is a very good table of specific gravities, published in the second volume of Musschenbroeck's *Introductio ad Philosophiam Naturalem*, 1763, in which the author does more justice to English tin, putting the weight of a cubic foot of the *purest* sort equal to 7295 avoir. oun. One specimen of the purest sort of *Malacca* tin gave 7331, and another 6125 ounces a cubic foot, which is the lightest of all the tins which he examined.

pieces like icicles, by a smart blow of an hammer*: tin in this form is called by our own manufacturers *grain tin*, by foreigners *virgin tin*, or *tears* of tin: and they tell us, that its exportation from Britain is prohibited under pain of death†. The tin which I used in the following experiments, was of this sort, but I first melted it, and let it cool gradually; a circumstance, I suspect, of some consequence in determining the specific gravity not only of tin, but of other metals. I have put down in the following table, the specific gravity of this tin, and of the lead I mixed with it by fusion, and of the several mixtures when quite cold; the water in which they were weighed was 60°.

Weight of a cubic foot of lead, tin, &c.

Lead	-	-		11270 oz. avoir.
Tin	-	-		7170
Tin	32 parts,	lead	1	—7321
Tin	16	—	lead 1	—7438
Tin	10	—	lead 1	—7492
Tin	8	—	lead 1	—7560
Tin	5	—	lead 1	—7645
Tin	3	—	lead 1	—7940
Tin	2	—	lead 1	—8160
Tin	1	—	lead 1	—8817

Blocks of tin are often melted by the pewterers into small rods; I think the rods are not so pure, as the

* This property is not peculiar to tin, I have seen masses of lead which, under similar circumstances, exhibited similar appearances, and it has been observed, that zinc, when heated till it is just ready to be fused, is brittle.

† Ency. Franç and Mr. Baume calls it etain en roche, a cause que sa forme resemble a des stalactites; he says also, that its exportation is prohibited, but that he does not see the reason for the prohibition, as it is not more pure than Cornish tin: and in this observation he is right, it is nothing but Cornish tin in a particular form. Chym. par M. Baume, vol. III. p. 422.

grain tin; at least, I found that a cubic foot of the specimen I examined, weighed 7246 ounces; but even this sort exceeds in purity any of the kinds examined by the authors above mentioned. Chemistry affords certain methods of discovering the quantity of lead with which tin is alloyed, but these methods are often troublesome in the application; an enlarged table, of the kind of which I have here given a specimen, will enable us to judge with sufficient precision of the quantity of lead contained in any mixture of tin and lead, of which we know the specific gravity. Pewterers, however, and other dealers in tin, use not so accurate a method of judging of its purity, but one founded on the same principle; for the specific gravities of bodies being nothing but the weights of equal bulks of them, they cast a bullet of pure tin, and another of the mixture of tin and lead, which they want to examine, in the same mould; and the more the bullet of the mixture exceeds the bullet of pure tin in weight, the more lead they conclude it contains.

Pewter is a mixed metal; it consists of tin united to small portions of other metallic substances, such as lead, zinc, bismuth, and the *metallic part*, commonly called, *regulus of antimony*. We have three sorts of pewter in common use; they are distinguished by the names of *plate—trifle—ley*. The plate pewter is used for plates and dishes; the trifle chiefly for pints and quarts; and the ley-metal for wine measures, &c. Our very best sort of pewter is said to consist of 100 parts of tin, and of 17 of regulus of antimony,* though others allow only 10 parts of regulus to 100 of tin†; to this composition the French add a little copper. Crude antimony, which consists of nearly equal portions of sulphur and of a metallic

* Med. Trans. vol. I. p. 286.
† Pemb. Chem. p. 322.

substance, may be taken inwardly with great safety; but the metallic part, or *regulus*, when separated from the sulphur, is held to be very poisonous. Yet *plate* pewter may be a very innocent metal, the tin may lessen or annihilate the noxious qualities of the metallic part of the antimony. We have an instance somewhat similar to this in standard silver, the use of which has never been esteemed unwholesome, notwithstanding it contains near one twelfth of its weight of copper. Though standard silver has always been considered as a safe metal, when used for culinary purposes; yet it is not altogether so, the copper it contains is liable to be corroded by saline substances into verdigris. This is frequently seen, when common salt is suffered to stay a few days in silver salt-cellars, which have not a gold gilding; and even saline draughts, made with volatile salt and juice of lemons, have been observed to corrode a silver tea spoon, which had been left a week in the mixture.

The weight of a cubic foot of each of these sorts of pewter is,

Plate	-	7248
Trifle	-	7359
Ley	-	7963.

If the plate pewter be composed of tin and *regulus* of antimony, there is no reason to expect, that a cubic foot of it should be heavier than it appears to be; since *regulus* of antimony, according to the different ways in which it is made, is heavier or lighter than pure tin. A very fine silver-looking metal is said to be composed of 100 pounds of tin, 8 of regulus of antimony, 1 of bismuth, and 4 of copper. The *ley* pewter, if we may judge of its composition by comparing its weight with the weights of the mixtures of tin and lead, mentioned in the table, contains not so much as a third, but more than a fifth part of its weight of lead; this quantity of lead is far too much,

considering one of the uses to which this sort of pewter is applied; for acid wines will readily corrode the lead of the flaggons, in which they are measured, into sugar of lead; this danger is not so great with us, where wine is seldom sold by the measure, as it is in other countries where it is generally sold so, and their wine measures contain, probably, more lead than ours do. Our English pewterers have at all times made a mystery of their art, and their caution was formerly so much encouraged by the legislature, that an act of parliament was passed, rendering it unlawful for any master pewterer to take an apprentice, or to employ a journeyman who was a foreigner. In the present improved state of chemistry, this caution is useless; since any one tolerably skilled in that science, would be able to discover the quality, and quantity of the metallic substances, used in any particular sort of pewter; and it is not only useless now, but one would have thought it must have been always so; whilst tin, the principal ingredient, was found in no part of Europe in so pure a state, nor in so great plenty as in England.

Borlase and *Pryce*, who have written so minutely on the method of preparing the tin in *Cornwall*, are both of them silent, as to any operation the tin undergoes subsequent to its coinage; nor do they say any thing of its being mixed with other metallic substances previous to its coinage; but assure us, that the tin, as it flows from the ore, is laded into troughs, each of which contains about three hundred pounds weight of metal, called slabs, blocks, or pieces of tin, in which *size* and *form* it is sold in every market in Europe. Foreigners, however, in general assert, that our tin as exported is a mixed metal; and the *French Encyclopedists* in particular (article *etain*) inform us, on the authority of Mr. *Rouelle*, that the virgin tin is again melted and cast into iron moulds of half a foot in thickness; that the metal is cooled very slowly; that

when cold it is divided horizontally into three layers; that the uppermost, being very soft pure tin, is afterwards mixed with copper, in the proportion of 3 pounds of copper to 100 of tin; that the second layer, being of a harsher nature, has 5 pounds of lead added to an 100 of the tin; and that the lowest layer is mixed with 9 pounds of lead to an hundred of the tin; the whole is then re-melted, and cooled quickly, and this, they say, is the ordinary tin of England; and *Geoffroy* had formerly given much the same account.* There is, probably, no other foundation for this report, but that pewter has been mistaken for tin, these metals being sometimes called by the same name; and fine pewter being sometimes made from a mixture of 1 part of copper with 20 or 30 parts of tin.

The mixture generally used for the tinning of copper vessels, consists of 3 pounds of lead, and of 5 pounds of pewter; when a finer composition is required, ten parts of lead are mixed with sixteen of tin; or one part of lead with two of tin; but the proportions in which lead and tin are mixed together, even for the same kind of work, are not every where the same; different artists having different customs. Vessels tinned with pure tin, or with the best kind of pewter, which contains no lead, do not stain the fingers when rubbed with them: whilst those which are tinned with a composition, into which lead enters as a constituent part, colour the fingers with a blackish tinge.

* —— fusores aperto furni ostiolo, metallum in formas quasdam ex arena paratas diffluere sinunt, ibique in massas grandiores concrescit. Superior stanneæ massæ pars adeo mollis est et flexilis ut sola elaborari nequeat sine cupri miscela, trium scilicet librarum super stanni libras centum. Massæ pars media binas tantum cupri libras recipit. Infima vero adeo fragilis est et intractabilis, ut cum hujus metalli centum libris plumbi libras octodecim consociare oporteat. Geoff. Mat. Med. vol. I. p. 282.

Zinc was long ago recommended for the tinning of copper vessels, in preference both to the mixture of tin and lead, and to pure tin* : and zinc certainly has the advantage of being harder than tin, and of bearing a greater degree of heat before it will be melted from the surface of the copper; so that on both these accounts it would, when applied on the surface of copper, last longer than tin; just as tin, for the same reasons, lasts longer than a mixture of tin and lead. But whether zinc makes any part of the compound metal for tinning copper, so as to prevent the necessity of repeated tinning, for which a patent was granted some years ago, is what I cannot affirm. Whatever may be the excellence of that composition, or of any other composition, which may be invented with respect to its durability, and its not contracting rust; still it ought not to be admitted into general use, till it has been proved, that it is not soluble in vegetable acids, or that its solutions are not noxious.† A method has of late years been introduced at *Rouen*, of applying a coat of zinc upon *hammered* iron sauce-pans. The vessels are first made very bright, so that not a black speck can be seen; they are then rubbed with a solution of sal ammoniac, and afterwards dipped into an iron pot full of melted zinc, and being taken out, the zinc is found to cover the surface of the iron; and if a thicker coat of zinc is wanted, it may be obtained by dipping the vessel a second time. This kind of covering is so hard, that the vessels may be scoured with sand without its being rubbed off.‡

* Mem. de l'Acad. des Scien. a Par. 1742.

† This doubt with respect to zinc is said to have been removed. M. de la Planche, a physician at Paris, tried the experiment on himself: he took the salts of zinc, formed by the vegetable acids, in a much stronger dose than the aliments prepared in copper vessels, lined with zinc, could have contained, and he felt no dangerous effects from them. Fourcroy's Chem. vol. I. p. 442.

‡ Journ. de Phy. Decem. 1778.

Kitchen utensils, which are made of cast iron, are usually tinned to prevent the iron's rusting; and, as great improvements have been lately made in rendering cast iron malleable, it is not unlikely, but that tinned iron vessels may become of general use.

The common method of tinning, consists in making the surface of the copper vessel quite bright, by scraping it, and by washing it with a solution of sal ammoniac; it is then heated, and the tin, or metallic mixture designed for tinning, is melted, and poured into it, and being made quickly to flow over every part of the surface of the vessel, it incorporates with the copper, and, when cold, remains united with it. Rosin or pitch are sometimes used, to prevent the tin from being calcined, and the copper from being scaled, either of which circumstances would hinder the sticking of the tin.

I had the curiosity to estimate the quantity of pure tin, which is used in tinning a definite surface of copper. The vessel was accurately weighed before and after it was tinned, its surface was equal to 254 square inches; its weight, before it was tinned, was 46 ounces, and its weight, after the operation, was barely 46 1-2 ounces; so that half an ounce of tin was spread over 254 square inches, or somewhat less than a grain of tin upon each square inch. How innocent soever pure tin may be, yet the tenuity of the coat of it, by which copper vessels are covered, in the ordinary way of tinning, cannot fail to excite the serious apprehensions of those who consider it; for in the experiment which I have mentioned, the tin was laid on with a thicker coat than in the common way; instead of a grain, I suspect that not a quarter of a grain of tin is spread over a square inch in the common way of tinning. A discovery has been lately made at Paris of a method of giving to copper or iron a coat of any required thickness, by tinning them; the composition used for

the tinning is not mentioned, but it is said that a piece of copper, which in the common way of tinning only absorbed 21 grains of tin, absorbed of the new composition 432 grains, or above twenty times as much.* Till this discovery is generally known, our workmen should study to cover the copper with as thick a coat as they are able of pure tin. The danger from the *corrosion* or *solution* of the tin by vinegar, juice of lemons, or other vegetable acids, if any at all, cannot, it is apprehended, be sensibly felt, except in very irritable habits, or where sour broths, sauces, or syrups are suffered to stand long in tinned vessels before they are used. And, indeed, a proper attention to keeping the vessels clean, might render the use of copper itself, for the boiling of food, especially of animal food, wholly safe. The French may be allowed to excel us in cookery, but we probably excel them in cleanliness; for the melancholy accidents attending the use of copper vessels, are much less frequent in England than in France; and this difference proceeds, I conjecture, from the superior care of the English in keeping their vessels clean, and from the cheapness and purity of the tin we use in tinning copper. We are not certain that the art of tinning copper vessels was known to the *Jews*, when they came out of *Egypt;* the vessels used in the temple service, were made of copper by divine appointment; and by being constantly kept clean, no inconveniences followed. The wort, from which malt liquor is brewed, is boiled in copper vessels; the distillers and confectioners, prepare their spirits and syrups in un-tinned vessels of the same metal, without our suffering any thing in our health from these practices; at least, without our being generally persuaded that we suffer any thing. A new copper vessel, or a copper vessel newly tinned, is more dangerous than after it

* L'Esprit des Journaux, Mai, 1785.

has been used; because its pores, which the eye cannot distinguish, get filled up with the substances which are boiled in it, and all the sharp edges of the prominent parts become blunted; and are thereby rendered less liable to be abraded.

M. de la Lande, in describing the cabinet at *Portici*, observes, that the kitchen utensils, which have been dug up at *Herculaneum*, are almost all of them made of a compound metal like our bronze, and that many of the vessels are covered with silver, but none of them with tin: and hence he concludes, that the useful art of applying tin upon copper, was unknown to the *Romans; cet art utile d' appliquer l' etain sur le cuivre manquoit aux Romains.** By the same mode of arguing, it might be inferred, that whatever is not met with in one house or town, is not to be found in a whole country: yet, should a town in England, in which there happened to be plenty of tinned, but no plated or silvered copper, be swallowed up by an earthquake, a future antiquary, employed in digging up its ruins, would make a bad conclusion, if he should thence infer, that the English understood, indeed, at that time the art of applying a covering of tin, but not one of silver upon copper. If the ingenious author had recollected what is said in the 34th book of *Pliny's* Natural History, he would have seen reason to believe, that the Romans, at least when Pliny wrote that book, did understand the method of tinning copper which is now in use; for this great naturalist assures us in express terms, that tin smeared upon copper vessels, rendered the taste more agreeable, and restrained the virulence of the copper rust. It is to no purpose to object, that the tin (stannum) of Pliny, was a substance different from our tin; for though it should be in some measure granted, that it was a mix-

* Voyage d' un Francois en Italie, vol. VII. p. 120.

ture of lead and silver, yet the same author tells us, in the same place, that white lead (*plumbum album*), by which it is universally allowed our tin is meant, was so incorporated with copper by boiling, that the copper could scarcely be distinguised from silver.* Nay, it appears that the Romans not only used pure tin, but the same mixture of tin and lead, which some of our workmen use at this time in tinning vessels. A mixture of equal parts of tin and lead, they called *argentarium;* a mixture of two parts of lead and one of tin, they call *tertiarium;* and with equal parts of *tertiarium* and tin, that is, with two parts of tin and one of lead, they tinned whatever vessels they thought fit. They, moreover, applied silver upon copper, in the same way in which they applied tin upon it;† and they used this silvered copper (I do not call it plated, because copper is plated by a different process) in ornamenting their carriages, and the harness of their horses,

* Stannum illitum æneis vasis, saporem gratiorem reddit, et compescit æruginis virus, mirumque, pondas non auget—from the weight of the copper not being *sensibly* increased (for Pliny here speaks popularly) we may infer, that the covering of tin which the copper received was very slight, and the art alluded to by Pliny in this place, was probably the same with that of tinning now in use—album (scil. plumbum) incoquitur æreis operibus, Galliarum invento, ita ut vix discerni possit ab argento, eaque incoctilia vocant. This description seems to be expressive of the manner of tinning, by putting the copper into melted tin, as is practised in the tinning of iron plates. Plin. Hist. Nat. L. XXXIV. S. XLIII.

† —— deinde et argentum incoquere simili modo cœpere equorum maxime ornamentis, &c. Id. ib.

To the preceding authorities I add that many utensils of copper plated with silver, have been found at Herculaneum. M. Beaume presented the Academy of Sciences with a plate of copper coated with silver (double d'argent) found in the Bourbonnois near Chentelles. On the border in relief was executed a sacrifice to Bacchus. Encyclop. quto. Tom. 6. p. 406. T. C.

as we now use plated copper; on this head Pliny observes, and a rigid philosopher will apply the observation to ourselves, that such was the luxury of the Romans, that it was then simply reckoned a piece of elegance to consume in the ornaments of coaches, and in the trappings of horses, metals, which their ancestors could not use in drinking vessels, without being astonished at their own prodigality: we are not yet, however, arrived at the extravagance of *Nero* and his wife, who shod their favourite horses with gold and silver.

Pliny mentions an experiment as characteristic of tin—that when melted and poured upon paper, it seemed to break the paper by its weight, rather than by its heat; and Aristotle, long before Pliny, had remarked the small degree of heat which was requisite to fuse *Celtic* (*British*) tin.* This metal melts with less heat than any other simple metallic substance, except quicksilver; it requiring for its fusion not twice the heat in which water boils; but compositions of tin and lead, which are used in tinning, melt with a still less degree of heat, than what is requisite to melt simple tin: and a mixture composed of 5 parts of lead, 3 of tin, and 8 of bismuth, though solid in the heat of the atmosphere, melts with a less degree of heat, than that in which water boils.†

Pewter vessels may be used for vinegar provided the tin in the composition be 82 per cent. The finest kinds of pewter contain no lead, but a small quantity of antimony and copper. Sometimes Bismuth forms a part of the alloy. Vallerius gives for pewter 12 parts tin, 1 antimony and 1-48th of a part copper. Or, 100 tin, 8 antimony, 1 bismuth and 4 copper. Tin 30 parts, zinc 1 part, brass one part, is a good alloy. 4 *Watson* 158—190.

* De Mirab.

† Discovered not by S. Is. Newton, but by Rozel. T. C.

Of tinning Iron.—Of plating and gilding Copper.

Iron is tinned in a different manner from copper. In some foreign countries, particularly in *France*, *Bohemia*, and *Sweden*, the iron plates, which are to be tinned, are put under a heavy hammer which gives, in some works, 76 strokes in a minute: they can in one week, with one hammer, fabricate 4320 plates; the iron is heated in a furnace eight times, and put eight times under the hammer during the operation, and it loses near an eighth part of its weight. Iron and copper are both of them very apt to be scaled by being heated, and they thereby lose greatly of their weight. Twenty-four hundred weight of pure plate copper, will not, when manufactured into tea-kettles, pans, &c. give above twenty-three hundred weight. Twenty-one hundred weight of bar iron will give a ton, when split into rods, but taking into consideration all iron and steel wares, from a needle to an anchor, it is estimated that thirty hundred of bar iron will, at an average, yield a ton of wares.* Thirty hundred weight of *cast* iron is reduced to twenty, when it is to be made into *wire;* and twenty-six to twenty-two, when it is to be made into *bar* iron. Steel suffers a much less loss of weight in being hammered, than iron does. *Cast* steel does not lose above two parts, and *bar* steel not above four in one hundred, when drawn into the shape of razors, files, &c. The iron plates in England, are not hammered, but rolled to proper dimensions by being put between two cylinders of cast iron cased with steel. This method of rolling iron is practised in *Norway*, when they form the plates with which they cover their houses; but whether it was invented by the English, or borrowed from some other country, (as many of our inventions in

* See an instructive pamphlet, intitled, A Reply to Sir L. O'Brien, by W. Gibbons, 1785.

metallurgy have been, especially from Germany,) I have not been able to learn. In the first account which I have seen of its being practised in England, it is said to have been an invention of Major *Hanbury* at *Pontypool*, the account was written in 1697, and many plates had then been rolled.* The *milling* of lead, however, which is an operation of the same kind, had been practised in the year 1670; for an act of parliament was passed in that year, granting unto Sir *Philip Howard*, and *Francis Watson*, Esq; the sole use of the manufacture of milled lead, for the sheathing of ships. A book was published in 1691, intitled, *The New Invention of Milled-Lead for sheathing of Ships*, &c. It appears from this book, that about 20 ships, belonging to the navy, had been sheathed with lead; but the practice was discontinued, on account of the complaints of the officers of the navy, that the rudder irons and bolts under water, had been wasted to such a degree, and in so short a space of time, as had never been observed upon any *unsheathed* or *wood-sheathed ships*. The persons then interested in sheathing with lead, published a sensible defence; and amongst other things, they remarked, that both the Dutch and English had ever been in the habit of sheathing the stern-posts and the beards of the rudders with lead or copper; and that the Portuguese and Spaniards did *then* sheath the whole bodies of their ships, even of their gallions, with lead, and had done it for many years. Copper sheathing has since taken place in the navy, but it is said to be liable to the same objections which were, above a century ago, made to lead sheathing. It is preferable, however, to lead, on account of its lightness. If the fact should be once well established, that ships sheathed with lead or copper, will not last so long as those which are unsheathed, or sheathed only

* Phil. Trans. Ab. vol. V.

with wood; it would be a problem well deserving the consideration of chemists, to inquire into the manner how a metallic covering operates in injuring the construction of the ships, and whether that operation is exerted on the iron bolts, or on the timbers of the ship.*

When the iron plates have been either hammered or rolled to a proper thickness, they are steeped in an acid liquor, which is produced from the fermentation of barley meal, though any other weak acid would answer the purpose: this steeping, and a subsequent scouring, cleans the surface of the iron from every speck of rust or blackness, the least of which, would hinder the tin from sticking to the iron, since no metal will combine itself with any earth, and rust is the earth of iron. After the plates have been made quite bright, they are put into an iron pot filled with melted tin; the surface of the melted tin is kept covered with suet or pitch, or some fat substance, to prevent it from being calcined; the tin presently unites itself to the iron, covering each side of every plate with a thin white coat; the plates are then taken out of the melted tin, and undergoing some further operations, which render them more neat and saleable, but are not essential to the purpose of tinning them, they are packed up in boxes, and are every where to be met with in commerce under the name of tin-plates; though the principal part of their substance is iron, and hence the French have called them *fer blanc*, or white iron: Sir *John Pettus* says, that they were with us vulgarly called *latten;* though that word more usually I think denoted brass.

Tin is not, but iron is liable to contract rust by exposure to air and moisture, and hence the chief use of

* It is owing to the oxydation of the iron and the copper, arising from the galvanic action of each on the other. The bolts and nails should be of copper. T. C.

tinning iron, is to hinder it from becoming rusty; and it is a question of some importance, whether iron of a greater thickness than the plates we have been speaking of, might not be advantageously tinned. I desired a workman to break off the end of a large pair of pincers, which had been long used in taking the plates out of the melted tin; the iron of the pincers seemed to have been penetrated through its whole substance by the tin; it was of a white colour, and had preserved its malleability. It is usual to cover iron stirrups, buckles, and bridle bits, with a coat of tin, by dipping them, after they are made, into melted tin; and pins, which are made of copper wire, are whitened, by being boiled for a long time with granulated tin, in a lye made of alum and tartar. Would the iron bolts used in ship building, be preserved from rusting by being long boiled in melted tin?—Would it be possible to *silver* iron plates by substituting melted silver for melted tin? I do not know that this experiment has ever been tried; but an intelligent manufacturer will see many advantages which would attend the success of it.

It is customary, in some places, to alloy the tin, used for tinning iron plates, with about one seventieth part of its weight of copper; foreigners make a great secret of this practice; I do not know whether any of our manufacturers use copper, some of them I have reason to believe do not. Too much copper renders the plates of a blackish hue, and if there is too little, the tin is too thick upon the plates; but this thickness, though it may render the plates dearer, or the profit of the manufacturer less, will make them last longer. When the tin is heated to too great a pitch, some of the plates have yellowish spots on them; but the coat of tin is thinner, and more even, when the tin is of a great, than of a moderate heat; and the yellowness may be taken away, by boiling the plates for two or three minutes in lees of wine, or, where

they cannot be had, sour small beer, or other similar liquors, may, probably, be used with the same success. The quantity of tin used in tinning a definite number of plates, each of a definite size, is not the same at different manufactories. In some fabrics in *Bohemia*, they use 14 pounds weight of tin for making 300 plates, each of them being 11 1-5 inches long by 8 1-2 broad; according to this account, one pound of tin covers a surface of 28 1-3 square feet: in other, where the tin is laid on thicker, one pound will not cover above 22 square feet; the thickness of the tin, even in this case, is small, not much exceeding the one thousandth part of an inch; though that is near twice the thickness which tin has upon copper in the ordinary way of tinning. I have enquired of our English manufacturers concerning the quantity of tin used by them in covering a definite surface of iron, and from what I could collect, it is very nearly the same with that used in Bohemia, from whence we derived the art of tinning, or 28 square feet to a pound of tin.

There are various *tin plate* manufactories established of late years in different parts of England and Wales. Saxony, and part of Bohemia formerly supplied all the known world with this commodity; but England now exports large quantities of it to Holland, Flanders, France, Spain, Italy, and other places. About the year 1670, Andrew Yarranton (he deserves a statue for the attempt) undertook, at the expence of some enterprising persons, a journey into Saxony, in order to discover the art of making tin plates; he succeeded to his utmost wishes; and, on his return, several parcels of tin plates were made, which met with the approbation of the tin men in London and Worcester.* Upon this success, preparations were made for setting up a manufactory, by the same persons who

* England's improvement by sea and land, by And. Yarranton, Gent. 1698.

had expended their money in making the discovery; but a patent being obtained by some others, the design was abandoned by the first projectors, and the patentees never made any plates; so that the whole scheme seems to have been given up till the year 1720, when the fabricating of tin plates made one of the many very useful projects, (though they were mixed with some which were impracticable) for which that year will ever be memorable. How soon after that year the manufacture of tin plates gained a lasting establishment, and where they were first made, are points on which I am not sufficiently informed; an old Cambridge workman has told me, that he used them at Lynn, in Norfolk, in the year 1730, and that they came from Pontypool. The tin men, at the first introduction of the English plates, were greatly delighted with them; they had a better colour, and were more pliable than the foreign ones, which were then, and still continue to be hammered; it being impossible to hammer either iron or copper to so uniform a thickness, as these metals are reduced to by being rolled. It is said, that a Cornish tin man flying out of England for a murder in 1243, discovered tin in Saxony, and that before that discovery, there was no tin in Europe, except in England;* a Romish priest, converted to be a Lutherian, carried the art of making tin plates from Bohemia into Saxony about the year 1620;† and Andrew Yarranton, as we have seen, brought it from Saxony into England about the year 1670; Saxony at that time being the only place in which the plates were made. They are now made not only in England, but in France, Holland, Sweden, &c. though from the cheapness of our tin, and the excellency of some sorts of our iron, the greatest share of the tin plate trade must ever centre with ourselves. Our *coal* is another cir-

* Heylin's Geog. † Yarranton.

cumstance, which tends to give Great Britain an advantage, over some other countries, in such manufactures as require a great consumption of fuel. *Wood* was scarce in Saxony above a century ago, and it is now still more scarce in France. They are beginning, it is said, in that country to use coal and coak, or charred pitcoal, called by them *Charbon de terre epure*, and they have granted a patent to an individual for the preparation of it.* Another individual has began to distil tar from pitcoal, and he gets about 5 pounds weight of tar from an hundred of coal (which is pretty nearly what I suggested in 1781, as possible to be obtained from the same quantity, vol. II. p. 352.) The French† expect great advantage from this mode of depurating coal, but we have nothing to apprehend on that score, for the patriotic zeal of the Earl of Dundonald has put us in possession of every advantage which can be expected from a discovery, which he has had the honour of bringing to perfection.

I do not know whether any attempt has ever been made to plate copper with tin instead of silver; I am aware of some difficulty, which might attend the operation, but yet it might, I think, be performed; and if it could, we might then have copper vessels covered with a coat of tin of any required thickness, which is the great *desideratum*

* Acad. des Scien. a Paris, 1781; where M. Lavoisier gives an useful memoir on the comparative excellencies of pit-coal, coak, wood and charcoal as fuels. Il suit de ces experiences, que pour produire des effets egaux, il faut employer: charbon de terre 600 livres; charbon de terre charbonne 552; charbon de bois mele 960; bois de hetre 1125; bois de chene 1089.

† Il suffit de dire qu' elle peut fournir a la capitale un nouveau chauffage, devenu necessaire dans un moment ou l' on est menace d' une disette de bois; qu' elle peut ouvrir dans le royaume une nouvelle brance de commerce; etablir de nouvelles manufactures; faire valoir des mines, restees jusqu' a present inutiles. L'Esprit des Journ. Juillet, 1785.

in the present mode of tinning: but it ought to be remarked, that the thicker the coat of tin, the more liable it would be to be melted off the copper by strong fires.

4 *Watson*, 158.

Tin-plate or tinned iron (*Fer Blanc* of the French) holds an intermediate place between an alloy and a coating. It is made simply by immersing plates of iron into melted tin, whereby they not only become covered with a perfect coating of this metal, but a very intimate union of the two metals takes place, to a certain depth in the substance of the iron, which is seen by cutting it transversely, and when the tinning has been repeated two or three times, the whole plate is more or less alloyed, or as it were, soaked with the tin.

Tin-plate is manufactured in several countries, but no where to such perfection as in England, to judge by the quantity exported. The finest kind when highly polished, has a lustre and whiteness scarcely inferior to silver, and the peculiar excellence of the English plate, appears to be chiefly owing to the perfect smoothness given to the plate before tinning, and the great uniformity in the application of the metallic coating.

The general process is extremely simple, and is thus described by Mr. Donovan.

It is carried on near Caermarthen in South Wales, the centre of an immense and increasing manufacturing district, of many of the most important metals.

The iron ore employed in this manufactory, is the common kind of the country, intermixed with a large portion of the fine hæmatite from Ulverstone, in Lancashire, which gives a very fine metal. This too is smelted with charcoal, instead of coke, to produce a metal of the greatest purity and extensibility, and closeness of texture, which qualities are particularly required in this manufacture. The reduced ore is smelted in the usual manner, and cast

into pigs, which are then wrought by the hammer into long flat bars, that are afterwards cut into pieces of about ten inches in length. These are then wrought into plates by being heated red-hot, and passed through a flatting mill, which consists of two large cylinders of steel, case-hardened, and secured in a frame of iron. These are placed contiguous to each other, but with a certain interval of space, and revolve in a contrary direction; so that when one end of the bar is thrust in the space between the cylinders, the whole is drawn through and proportionably extended and flattened in the passage. The distance between the cylinders, which of course determines the thickness of the plate, is maintained and regulated by screws, which can be altered at pleasure. When the bar is thus made into a plate of twice the thickness of the ordinary plates, it is heated red-hot, cut in two by a pair of shears, and one piece folded exactly over the other, and both repassed repeatedly through the cylinders, till the folded plate has extended to the same length and breadth as the plate was before cutting. It is then clipped round the edges, and the two plates torn asunder (which requires some little force) after which they are each finished by passing through a finer rolling-press, so as to take away every crease or inequality in the plate, and those that are too rough to pass through this finer press are thrown aside.

The plates are then steeped in a very weak acid liquor, and when taken out are scoured thoroughly with bran so as to be quite bright and polished to enable the tin to adhere. The tin is melted in deep rectangular crucibles, and kept fluid by a moderate charcoal fire beneath. To prevent its calcination a quantity of grease prepared from linseed-oil and suet is constantly kept floating on the surface of the tin and renewed as it evaporates off, which gives an excessively nauseous stench. The plate is then taken

up by one corner by a pair of pincers and dipped vertically into the tin, and when withdrawn is found beautifully white and resplendent with the coating of this metal that adheres to it. This dipping is repeated three times for what is called single tin plate, and six times for the double plate. The plates are then only cleansed and sorted, and are fit for use.

Some further particulars may be added from other authorities.

In many manufactories the iron plates before tinning are cleansed by being immersed in large barrels full of a mixture of rye-flour and water, sometimes with verjuice by which fermentation has become very acid. In Bohemia the plates remain three times twenty-four hours in tubs filled with this acescent mixture, in three different states, after which they are washed, scoured with sand and water, and kept under water till just before they are used, to avoid rusting again.

Attention is to be paid to the heat of the melted tin; if too hot the plate comes out yellow. The plates are immersed quite wet into the melted tin, passing in their way through the melted suet which covers it. Just before dipping, some water is thrown on the melted suet, which causes a violent ebullition and makes the surface of the metal quite clean and bright. The plates when tinned are set up to drain, by which a number of drops of tin collect in small knobs at the lower part. These are taken off by a second immersion into a separate cauldron of tin, but only to the depth of a few inches, by which the drops of tin melt down and the whole tinning is made more uniform in thickness. They are then cleansed with a rag and saw-dust or bran. About 19 1-2 pounds of tin are required for 300 plates, measuring 1 foot by 9 inches.

The manufacture of tin-plate in France appears to be

conducted so nearly in the same manner as not to require a separate description.

In the manufactures of tin-plate on the continent a quantity of copper is always added to the tin, but in very small proportion. The exact quantity is regulated by slight circumstances, which only experience can teach. It appears to be in general from one-eightieth to one hundred and twentieth of the tin. The copper prevents the tin from adhering in too great a quantity to the iron, and causes the superfluous part to drain off more freely. Too much copper gives a dull yellow tint.

It appears that the method of flattening the bar into plate by cylinders is only adopted in this country, but in other places is done by the hammer. [*Aikin.*

Upon this information, I would make the following remarks:

1st. Desirable as the manufacture of tin-plates would be in this country, we have as yet no iron plates, at all fit for the purpose: they are neither thin enough, or smooth enough, or pure enough.

2dly. The manufacturer of tin plates in *this* country, must roll out his own iron from bars picked by himself; or he will not have such as he can depend upon.

3dly. The rollers must be of the very best quality; otherwise they will not give the requisite thinness and smoothness to the iron plate. While the plate is rolled the rollers should be greased.

There is at this moment tin enough in the United States to supply more than a twelve months' consumption; but on the calculations I have made, no person can commence the manufacture of tin plates prudently, under a capital of 10 or rather 12,000 dollars. He must find his own water or steam engine power; he must find employment for his surplus power, when he is not rolling

iron plates. He cannot depend on the iron plates manufactured in this country, nor indeed on any that are not manufactured under his own eye. I make these remarks because I do not know a more tempting speculation than the manufacture of tinned iron plates in this country; nor any, where a person who does not sit down to calculate carefully all the requisites of such a manufacture *here*, may be more easily deceived.

Making of tinfoil. The tin is melted into ingots, and then hammered on a smooth iron plate. I do not know whether rolling has been tried. All the tin foil I have seen, appears to contain an admixture of lead. Tin foil is used for silvering looking glasses, and for coating electrical jars. In the latter case it is merely fastened on the glass with paste. But M. Sage's paper which I am about to give, will furnish information on this subject.

To coat looking glasses with Tinfoil and Mercury; commonly called the Silvering of looking glasses.

In order to go completely forward, you must be prepared with the following articles, viz.

First, A square marble slab, or smooth stone, well polished, and ground exceedingly true, the larger the better, with a frame round it, or a groove cut in its edges, to keep the superfluous mercury from running off. Secondly, Lead weights covered with cloth, to keep them from scratching the glass, from one pound weight to twelve pounds each, according to the size of the glass which is laid down. Thirdly, Rolls of tinfoil. Fourthly, Mercury or quicksilver, with which you must be well provided; then proceed as follows.

Cut the tinfoil a little larger than the glass every way, and lay it flat upon the stone, and with a straight piece of hard wood, about three inches long, stroke it every way,

that there be no creases or wrinkles in it, then drop a little mercury upon it, and with a piece of cotton, wool, or hair's foot, spread it all over the foil, so that every part may be touched with the mercury. Then keeping the marble slab nearly level with the horizon, pour on the mercury all over the foil, cover it with a fine paper, and lay two weights very near its lowest end or side, to keep the glass steady, while you draw the paper from between the silvered foil and the glass, which must be laid upon the paper. As you draw the paper, you must take care that no air bubbles be left, for they will always appear if left in at the first; you must likewise be sure to make the glass as clean as possible on the side intended to be silvered, and have the paper also quite clean, otherwise, when you have drawn the paper from under it, dull white streaks will appear, which are very disagreeable.

After the paper is drawn out, place as many weights upon the glass as you conveniently can, in order to press out the superfluous mercury, and make the foil adhere to the glass. When it has lain six or seven hours in this situation, raise the stone about two or three inches at its highest end, that as much of the mercury may run off as possible; let it remain two days before you venture to take it up; but before you take the weights off, gently brush the edges of the glass, that no mercury may adhere to them; then take it up, and turn it directly over, with its face side downward, but raise it by degrees, that the mercury may not drip off too suddenly; for if, when taken up, it is immediately set perpendicular, air will get in between the foil and the glass at the top, as the mercury descends to the bottom; by which means, if you be not exceedingly careful, your labour will be lost.

Another method, is to slide the glass over the foil, without the assistance of paper.

To Silver Glass Globes.

Take half an ounce of clean lead, and melt it with an equal weight of pure tin; then immediately add half an ounce of bismuth, and carefully skim off the dross; remove the mixture from the fire, and before it grows cold, add five ounces of mercury, and stir the whole well together; then put the fluid amalgam into a clean glass, and it is fit for use.

When this amalgam is used for foiling or silvering, let it first be strained through a linen rag; then gently pour some ounces thereof into the globe intended to be foiled; the mixture should be poured into the globe, by means of a glass or paper funnel, reaching almost to the bottom of the globe, to prevent its splashing to the sides; the globe should then be dexterously inclined every way, though very slowly, in order to fasten the silvering; when this is once done, let the globe rest some hours; repeat the operation, till at length the fluid mass is spread even, and fixed over the whole internal surface; as it may be known to be, by viewing the globe against the light; the superfluous amalgam may then be poured out, and the outside of the globe cleared.

To Silver the Convex side of Meniscus Glasses for Mirrors.

Take an earthen plate, on which pour some prepared plaster of Paris, mixed with water, of a proper consistence; then immediately, before it grows too stiff, lay the meniscus with its convex side downward, in the middle of the plate, and press it until it lies quite close to the plaster; in which situation let it remain until the plaster becomes quite dry; after which, work a groove with your finger, round the outside of the meniscus, in order to let the superfluous mercury rest upon it: then cut the tinfoil to a proper size, and press it with the meniscus into

the plaster mould, in order to make it lie close; after which, cover it with the mercury, and, without a paper, (as directed for silvering plain mirrors), slide it over the silvered foil; then place a weight on it, and let it stand two or three days, raising it by degrees, that the mercury may drip off gradually.

After this method common window glass, &c. may be silvered. [2 *Jamison's Elements*, 383.

Observations on the polishing of Glass, and on the Amalgam used for silvering Mirrors. By B. G. SAGE*.

Having been consulted in regard to the bad effects of some calces or red oxyds of iron, which alter the surface of glass by rendering it dull and yellowish, I analysed these calces of iron, and found out the cause on which this defect depends. Red calx or oxyd of iron, called *colcothar*, is employed with water for giving the last polish to glass intended for mirrors.

Were not the oxyd or calx of tin, commonly known by the name of *putty*, so dear, it would be far preferable to red calx or oxyd of iron, obtained by the decomposition of martial vitriol, either by calcining it in a fire proper for disengaging the acid or decomposing the sulphat of iron by marine salt. In the latter case, the red oxyd or calx of iron retains a little of that salt, which is of no hurt in the polishing of glass: but the case is not the same if the colcothar or red oxyd of iron retains martial vitriol. This salt, when dissolved in water, is decomposed, and the yellow ochre which results from it penetrates the glass, forms a crust on it, and renders it greasy, dull, and yellowish; a tint which is communicated to the image of the object presented to the mirror.

Glass when smoothed and polished does not acquire the property of reflecting objects till it has been *silvered*

* From the *Journal de Physique*, Thermidor, an 12.

(as it is called), an operation effected by means of an amalgam. The tin leaf employed must be of the size of the glass, because, when pieces of that metal are united by means of mercury, they exhibit the appearance of lines. Tin is one of those metallic substances which become soonest oxydated by the means of mercury. If there remains a portion of that calx, of a blackish gray colour, on the leaf of tin, it produces a spot or stain in the mirror, and the part where it is cannot reflect objects presented to it: great care, therefore, is taken in silvering glass to remove the calx of tin from the surface of the amalgam.

The process is as follows:—The leaf of tin is laid on a very smooth stone table, and mercury being poured over the metal, it is extended over the surface of it by means of a rubber made of bits of cloth. At the same moment the surface of the leaf of tin becomes covered with blackish oxyd, which is removed with the rubber. More mercury is then poured over the tin, where it remains at a level to the thickness of more than a line, without running off. The glass is applied in a horizontal direction to the table at one of its extremities, and being pushed forwards it drives before it the oxyd of tin which is at the surface of the amalgam. A number of weights are then placed on the glass which floats on the amalgam, in order to press it down. Without this precaution the glass would exhibit the interstices of the crystals resulting from the amalgam. These crystals have the form of large square laminæ irregularly disposed.

To obtain leaves of tin, which are sometimes six or seven feet in length, with a proportionate breadth, they are not rolled but hammered. The prepared tin is first cast between two plates of polished iron, or between two smooth stones not of a porous nature, such as thunder stone. Twelve of these plates are placed over each other;

and they are then beat on a stone mass with heavy hammers, one side of which is plain and the other rounded. The plates joined together are first beaten with the latter: when they become extended the number of the plates is doubled, so that they amount sometimes to eighty or more. They are then smoothed with the flat side of the hammer, and are beat till they acquire the length of six or seven feet, and the breadth of four or five. The small block of tin from which they are formed is at first ten inches long, six in breadth, and a line and a quarter in thickness.

When the leaves are of less extent, and thin, from eighty to a hundred of them are smoothed together.

Tin extracted from the amalgam which has been employed for silvering glass, exhibits a remarkable peculiarity. When fused in an iron pan, its whole surface becomes covered with a multitude of tetraedral prismatic crystals two or three lines in length and a quarter of a line in thickness. The interior of these pieces of tin, when cut with a chisel, have a grayer tint than pure tin, which is as white as silver. The latter crystallizes also by cooling; but it requires care. When it begins to be fixed, decant the part which is still in fusion, and there will remain at the bottom of the crucible beautiful crystals of a dull white colour, which appeared to me to be cubes or parallelopipedons.

The peculiar and constant crystallization of tin taken from the amalgam of mirrors, the leaden gray colour which the mass of this metal had, and the mystery made of the preparation of this tin, induced me to try whether I could not discover by analysis the substance mixed with it.

Having calcined this tin in a test, it was reduced to a powder of a delicate red colour, and increased in its weight 1-25th. The magnet attracted particles of iron, the re-

sult of the hammering. It appears that this metal concurs to produce the crystallization of the tin, and the singularity exhibited by the solution of its oxyd in nitric acid. At first, nothing is manifested but a slight effervescence, which soon subsides; but four or five minutes after, the mixtures become very hot, and a stronger effervescence takes place, accompanied with a great deal of nitrous gas, which is disengaged with an explosion, and there remains in the glass a magma of a pale red colour.

The white oxyd of tin, mixed also with nitric acid at 32°, exhibits neither effervescence nor disengagement of nitrous gas.

I fused this reddish calx of tin with three parts of black flux and a little charcoal powder, and extracted from it 18 pounds of tin per quintal. This metal was brittle, a property arising from the lead, which contributes also to attenuate the colour of the tin. If the lead is found there in larger quantity, it is because there are four-fifths of tin absorbed by the alkaline flux.

To determine the quantity of lead contained in the tin extracted from the amalgam of mirrors, I decomposed a hundred parts of it by four hundred parts of nitric acid at 32°. A great deal of nitrous gas was disengaged, and there remained at the bottom of the matrass a white magma. I washed it with distilled water, and evaporated the ley, which produced a twenty-fifth of nitrous ammoniacal salt mixed with nitrate of lead, which predominates, and forms nearly two-thirds of the saline residuum; a proportion which would indicate that the tin employed for silvering mirrors contains three pounds of lead per quintal.

I now return to the mercury extracted by distillation from this amalgam. It volatilizes a portion of tin, which remains there so intimately combined that it cannot be separated by a second distillation of the mercury. I was able to disengage from it the tin by shaking the mercury

with nitric acid, which attacks and oxydates the tin. I washed the mercury and strained it through a piece of linen. In this state it may be employed for gilding, but when it contains the smallest quantity of tin it stains the articles.

What I have related in this memoir shows that red oxyd of iron, known under the name of colcothar, is not proper for polishing glass when it contains vitriol; that the tin employed for silvering mirrors contains lead and iron; that when this tin is separated from the mercury by distillation this metal crystallizes with the greatest facility and without any precaution; and, in the last place, it is shown that a portion of tin is volatilized by the mercury during the distillation of the amalgam, and that it cannot be separated but by the nitric acid.

[22 *Phil. Mag.* 113.

To whiten Copper, Brass, or Iron Wire.

Pins are whitened thus. Tin is reduced into a kind of powder, by first melting it, and pouring it out into an iron mortar, bruise it fine just at the moment as it is set, and while still hot—or take grain tin, and granulate it by pouring it through a birch broom into water. The tin thus granulated, is put into a boiler with the brass or copper wire to be whitened, and boiled with alum and crude tartar, or argol. I do not know the exact proportions, but in this manner the wire is penetrated by the tin. One part tartar, two parts by weight alum, and as much common salt, will succeed. T. C.

It is not necessary to employ this mixture of salts for the mere tinning of copper or brass. Either of these three salts singly with tin filings will answer the purpose, but cream of tartar gives a duller and more leaden-looking tinning, and alum on the other hand gives a very fine sil-

ver white but without gloss, so that the mixture above mentioned is found to produce the most desirable hue.

In a chemical point of view this operation is curious, and appears to present a contradiction to the usual laws of affinity, for when tin is immersed in a common solution of copper, it precipitates most of the copper in the metallic state.

The circumstances requisite to produce a precipitate of metallic tin on copper, have been examined in an able set of experiments by Professor Gadolin, a Swedish chemist, an account of which is inserted in the Stockholm Transactions for 1788, to which are added some other experiments and remarks by Baron de Gedda. It is to be observed, that the circumstances relating to the oxygenation of metals in their solutions in acids were very incompletely known at that time, so that we may now account for phenomena which must have been inexplicable at that period. The facts however cannot vary, and are always valuable. This chemist chiefly confined himself to the action of a single salt, namely tartar, or its acid. We shall select and give in a few words some of the experiments.

1. Tartrite of potash was added to nitromuriat of tin, which caused a white precipitate of tartrite of tin, which was edulcorated and dried. Some of this precipitate was boiled with water, and copper was immersed, but the copper was in no degree altered.

2. Some of the above tartrite of tin was acidulated with tartareous acid and copper was boiled in it, but with no effect.

3. Some of the same tartrite of tin was treated as in the last experiment, but with the addition of some leaf-tin and the copper was now completely tinned.

4. The last experiment was repeated, but without an excess of acid, and no effect was produced on the copper.

5. Cream of tartar, tin filings, and a piece of copper, were boiled together, and the copper was completely tinned.

These experiments shew that in order to precipitate tin upon copper by means of tartar, it is necessary, both that some metallic tin should be present in the solution, and that the solution should contain an excess of acid.

6. Some oxyd of copper arising from the decomposition of blue vitriol by an alkali, was first boiled in a solution of cream of tartar, after which both tin-leaf and copper were introduced, and the whole boiled together for three hours. Both the copper and tin were covered with a crust of blackish metallic alloy.

7. Some copper was tinned by boiling with tin and a solution of tartar. The liquor after the copper was withdrawn was not changed to blue by volatile alkali, and hence was inferred to contain no copper, though when exposed to the light some faint blue streaks were observable.

8. The same experiment was repeated with tartar, alum, and salt, (the usual mode of tinning) and no indications of copper were furnished by the volatile alkali.

9. Copper was tinned with each of the above three salts singly, and in neither instance did the volatile alkali give any indications of dissolved copper in the liquor.

10. Tin-leaf was boiled for an hour with a solution of cream of tartar. The tin was then withdrawn and a bar of iron introduced, and the boiling continued. The iron was soon blackened at its surface, and after three quarters of an hour, was covered with a mixture of reduced metallic tin and oxyd of tin, and the iron had lost weight in the process.

Hence as iron was found to precipitate tin in a metallic state from its solution, it was conjectured that iron added to a solution of tin, in which copper was immersed, might

determine the tinning of the copper. The experiment however succeeded but imperfectly when tartar was used, owing to the languor of its action on iron, and even when a few drops of sulphuric acid were added, the tin was precipitated solely on the iron, whilst the surface of the copper remained unaltered, but with alum it was different.

11. Some tin-leaf was boiled with a solution of alum for half an hour and then withdrawn. Into the solution were then introduced a piece of polished copper, and some iron filings. The latter were acted on with much rapidity, and in a few minutes the copper was covered with a pellicle of tin, which in half an hour gave it the appearance of fine silver unpolished.

12. Tin-leaf and a solution of alum were boiled together. The tin was then taken out, and into the solution both iron and copper were introduced, each polished. After a few minutes boiling both these metals were highly tinned.

13. Some sulphat of copper was dissolved in water, tin-leaf was added, and the mixture was exposed to a moderate heat for some days in a well closed phial. In a few days the colour of the solution entirely disappeared, and the copper precipitated to the bottom of the vessel. The clear supernatant fluid was distributed into three phials, into the first of which was put copper and tin; into the second, copper and iron; and into the third, copper alone. They were well corked, and after digestion in moderate heat for some hours the copper in the first phial, and the copper and iron in the second were well tinned, but the copper in the third remained unaltered.

From the above experiments we may clearly make out that the state of the solution of tin, when it is disposed to precipitate in a metallic form on the surface of copper

immersed in it, is that of the lowest degree of oxydation, which is obtained either by keeping some undissolved tin in the solution or (Exp. 10 and 11) by introducing iron. The great difficulty which occurred to the author of these experiments was to account for the precipitation of the tin when there did not appear to be any copper dissolved during the process, for in all other metallic precipitations (as that of copper on iron for example) the separation of one metal from the solution is attended with the solution of a corresponding quantity of the other metal.

The difficulty is increased too by the fact that when tin is immersed in a solution of copper the copper is precipitated, and a portion of the tin is dissolved, so that the direct affinity of acids for tin is greater than for copper.

The hypothesis given by Professor Gadolin to explain this is highly ingenious. He observes that as a very strong affinity exists between tin and copper, this affinity operates on the metallic part of the solution of the tin immediately in contact with the copper, and causes its separation in the metallic form, whilst the remainder of the tin, which is the greatest portion, undergoes a greater degree of calcination (i. e. oxygenation) and hence too the solution after its utmost action on copper still retains a quantity of tin. In other words, the dissolved tin divides itself into two portions, one of which returns to the metallic state, and adheres to the copper, whilst the whole of the oxygen condenses in the other portion, which remains dissolved.

To shew that a corresponding solution of the *precipitant* (i. e. the copper) is not necessary to the separation of the *precipitate*, M. Gadolin boiled some fine gold with tin and tartar, and after a short time the gold was completely covered with a coating of reduced tin, and it cannot be supposed that any of the gold should have been dissolved by the tartar. This experiment would have been

more complete if the tin had been again separated from the gold by muriatic acid, and the gold had been weighed before and after the operation, but if this statement is accurate (which there is no apparent reason to doubt) it is a curious fact, and one for which in addition to M. Gadolin's explanation, we must probably refer to the late discovered experiments in Galvanism. This is confirmed by the circumstance that in every one of the experiments on tinning above related, the presence of two dissimilar metals in the reguline state is required, so that the moment the metallic tin is withdrawn from the tartareous solution the precipitation of tin upon copper ceases, though we can hardly suppose that any immediate change in the state of oxygenation of the solution takes place.

With respect to the circumstance of no copper being found in the solution of tartar after common tinning, we may observe however that the failure of the usual test of the volatile alkali is no certain proof of the absence of this metal in this instance, as the later discoveries of Proust on this subject (which are detailed under the article *Copper)* shew that when copper is in solution with tin in a low state of oxydation, it is so far deprived of oxygen by the tin, as not to turn blue with ammonia.

The experiments in which iron, copper, and tin were immersed into a solution of tin, are complicated, and the exact operation of all the affinities between the respective substances is not easily made out. The order of precipitation with a single metal, and a single metallic solution, is copper, tin, iron; that is to say, iron immersed into a solution of tin displaces the tin, and precipitates it mostly in the metallic form; and tin immersed into a solution of copper precipitates the latter metal. But in the above complicated case both the iron and copper become tinned, so that the tinning of the iron may be effected by simple and direct affinity, but that of the cop-

per requires a complicated action, to which probably the metallic tin present contributes. [2 *Aikin*, 427.

It has been proposed to whiten copper, brass, and iron, in this manner by means of silver, or of zinc; but I do not know of any decisive experiment to this purpose. The proposal is at least very plausible.

Aurum Musivum or Mosaicum. See 61 Phil. Trans. 114. 13 Ann de Chimie, 280.

I copy the following account of this substance from Aikin, to which, at the expence of some tautalogy, I shall add my own notes.

"A beautiful golden-coloured species of sulphuret of tin has long been known in the arts, under the name of *Aurum Musivum* or *Mosaicum*, *(Mosaic Gold)*. It is in the form of a scaly mass, sometimes crystallized in six-sided plates, very soft and glossy to the touch, readily rubbed down between the fingers, and when the colour is brought out by a little friction, having a fine golden metallic lustre. It is still prepared in pretty large quantities by some artists, and is supposed to be used principally in artificial bronzing and other ornamental purposes. It was formerly employed in medicine. A great number of receipts have been given for preparing it, most of which succeed nearly equally well, provided the same attention to management of the heat, &c. be observed. It is also interesting to experimental chemistry, and its properties have been examined by several excellent chemists, among whom may be enumerated Mr. Woolfe, the Marquis de Bullion, and M. de Pelletier.

The old process for aurum musivum, and which is one of the best, is the following; as contained in the London Dispensatory.

Take 12 oz. of tin, 7 oz. of flowers of sulphur; sal ammoniac and quicksilver, of each 6 oz. melt the tin by

itself, add to it the quicksilver, and when the amalgam is cold reduce it to powder, and mix it with the sulphur and sal ammoniac, and sublime the whole in a glass matrass, standing in a sand-bath. Apply a gentle fire for some time, 3 or 4 hours, till the white fumes which arise copiously at first, begin to abate, then raise the fire till the sand becomes red-hot, and keep it at this point, neither increasing nor diminishing it, for a considerable time, according to the quantity of the materials, till you judge the operation to be completed. The matrass being broken when cold, the mosaic gold is found at the bottom, and above it a sublimed substance, the composition of which will be presently mentioned.

The mosaic gold therefore is not a *sublimate*, but is a fixed substance, and it cannot be raised by heat unchanged. It weighs considerably more than the tin employed, but the actual product is extremely uncertain. A good deal of care is required in managing the fire, for if too slack none of the mosaic gold will be formed, and if urged beyond a moderate redness it is again decomposed into a dark sulphuret of tin, totally without lustre. The proportions of the ingredients are variously given. Formerly equal parts of all the substances were employed, but they may be reduced to the proportions here given without diminishing the product.

As soon as the ingredients are mixed an odour of sulphuretted hydrogen is given out, which increases rapidly as heat is applied; and if the process be performed in a retort, with a receiver attached to it, a quantity of hydrosulphuret of ammonia or volatile silver of sulphur, comes over, which condenses in the extremity of the receiver, partly as a liquid and partly in beautiful crystalline needles. The sublimate which is formed above the aurum musivum, and which is much less volatile than the ammoniacal hydro-sulphuret, is an extremely compound

substance, (in the usual way of preparing it) consisting chiefly of cinnabar, of muriated ammonia, and some muriat of tin, from which by a fresh sublimation an additional quantity of the aurum musivum may be obtained. This latter appears to be contained in the first sublimate, and indeed may often be found interspersed in it in shining hexagonal plates, but as aurum musivum alone cannot be sublimed, this portion is supposed to be formed by the muriat of tin and sulphur combining in the act of volatilization.

The decompositions and changes that take place in the preparation of aurum musivum with mercury, tin, muriat of ammonia, and sulphur, are numerous and somewhat complicated. The principal ones appear to be the following: the mercury at first seems nearly passive in the operation, and serves merely to divide the tin, and render it easily reducible to powder, but when the heat is increased the mercury volatilizes and unites with the sulphur into cinnabar. The tin is certainly first acted on by the sal ammoniac decomposing the water which it contains, the oxygen of which it absorbs, and the oxyd of tin thus produced is immediately dissolved by the muriatic acid of the sal ammoniac forming a muriat of tin. This process sets at liberty two very volatile substances, viz. the hydrogen of the water decomposed, and the ammonia of the salt, both of which, in volatilizing carry up a sufficient quantity of the sulphur present to constitute the hydro-sulphuret of ammonia, which flies off in white fumes in the common way of proceeding, or, as already mentioned, may be collected in a receiver joined to the apparatus.

The ingredients in the matrass are now changed, more or less completely, to muriat of tin, mercury, and sulphur; and as the heat is increased all the mercury and part of the sulphur sublime, and unite into cinnibar; the muriat

of tin is decomposed by another part of the sulphur, the muriatic acid is volatilized, taking with it a portion of the tin, and finally the remaining oxyd of tin and the rest of the sulphur, unite to form the aurum musivum that remains at the bottom of the vessel.

It is to be observed that the sole use of the mercury in this mixture is to enable the tin to be reduced to powder, so that the mixture may be simplified by omitting the mercury, provided the tin is reduced to powder, or otherwise divided. The ammonia of the sal-ammoniac is also entirely superfluous, and even the sole use of the muriatic acid is to enable the tin to oxydate itself by the decomposition of water, which it affects by the resulting affinity of oxyd of tin for muriatic acid. So that in fact the only necessary ingredients for aurum musivum appear to be oxyd of tin and sulphur, the latter in considerably larger proportion than it exists in the black sulphuret.

These observations will be explained and illustrated by a short abstract of a variety of other processes given by different chemists, by which aurum musivum may be made.

The three following are given by Mr. Woolfe.

Take 10 oz. of black sulphuret of tin, (formed by saturating melted tin with sulphur) mix it with 4 oz. of sulphur and 2 oz. of muriatic acid, calcine the mixture, and heat the residue in a matrass in the usual way. This gives a tolerably good aurum musivum.

2. Take 4 oz. of tin, saturate with sulphur, powder it well, and mix it with 2 oz. of sulphur and 1 oz. of crystallized muriat of tin. Calcine and heat as in the last process. This gives 6 1-2 oz. of a very fine aurum musivum.

3. Mix 10 oz. of black sulphuret of tin with 16 oz. of corrosive mercurial muriat, put it into a retort with a receiver adapted to it, and apply a heat for six hours, at

first with a moderate fire, and for the last three hours the retort must be red-hot.

In this process the mercurial muriat is decomposed, a portion of the tin rises highly oxydated, and united to the muriatic acid in the form of the smoking muriat; another portion remains behind, united with part of the sulphur into very beautiful aurum musivum, whilst the oxyd of mercury unites with another part of the sulphur into cinnabar.

The same experiment repeated by Pelletier, with equal parts of the two ingredients, gave the fuming muriat of tin, running mercury, and aurum musivum.

Brugnatelli gives the following receipt.

4. Precipitate a solution of nitrat of tin by liquid sulphuret of potash; dry the precipitate, mix it with half its weight of sulphur, and a quarter of sal-ammoniac, and heat as usual.

The following are some of the interesting experiments of Pelletier on this subject.

5. A solution of 600 grains of tin was made in muriatic acid; to this were added 600 grains of sulphur, and the whole was evaporated to dryness. It was then reduced to powder and heated in the usual way, and gave a sublimate of muriat of tin, mixed with a little sulphur, and the residue at the bottom of the vessel was very good aurum musivum.

6. Equal parts of tin filings, sulphur, and sal-ammoniac, were duly heated: the volatile products were hydrosulphuret of ammonia, sulphuretted hydrogen gas, sulphur, and some sal-ammoniac, and very fine aurum musivum remained.

7. Equal parts of black sulphuret of tin and muriat of ammonia were mixed and heated. The residue was a black, iridescent, friable, puffy mass, very different from the simple sulphuret, and appeared to be oxyd of tin,

not saturated with sulphur; and in this latter circumstance therefore differing from aurum musivum. This was confirmed by the following.

8. Equal parts of the black sulphuret of tin, of sal-ammoniac, and of sulphur, were heated as above, and a good quantity of fine aurum musivum was obtained. As there was more sulphur than necessary, some sulphuret of ammonia was sublimed.

9. Equal parts of cinnabar and black sulphuret of tin heated together, gave running mercury and aurum musivum. Cinnabar consists of sulphur and oxyd of mercury, so that the sulphuret of tin in this experiment deprived the cinnabar both of its oxygen and sulphur.

10. Equal parts of tin putty *(sub-oxyd of tin)* and sulphur gave, after much of the excess of sulphur had sublimed off, a black brittle mass, visibly penetrated with sulphur, but no aurum musivum.

11. Some tin putty was calcined with nitre, and thus converted into a white oxyd. Of this, 600 grains were heated with 400 of sulphur, and the products were, sulphur and sulphureous gas, and aurum musivum.

12. The oxyd of tin, precipitated from the muriat of soda, and mixed with sulphur, gave the same products as the last.

13. The oxyd of tin by nitric acid, mixed with two-thirds of its weight of sulphur, gave the same products as the last.

In examining these experiments it appears that aurum musivum may be made simply by heating sulphur and oxyd of tin, but the three last experiments shew that it is necessary for the tin to be in a state of high oxygenation.

Nevertheless, as in these simple processes some of the sulphur is converted into sulphureous acid, for the oxygen of which no other source but the oxyd of tin appears, it may be doubted whether the tin remains in the highest

state of oxygenation in the aurum musivum, though there can be no doubt that it is oxydated to a certain degree.

We may therefore consider this substance as a sulphuretted oxyd of tin, in which the oxyd is saturated with as much sulphur as it can retain at a low red heat.

Aurum musivum may be made as well, and much more economically, in a crucible as in glass vessels. To make 10 or 12lb. of it requires about eight hours; but for an ounce or two in small experiments about an hour will suffice.

Aurum musivum, when well prepared, is without taste, and entirely insoluble in water. The acids have no effect on it. When muriatic acid is boiled with it, some sulphuretted hydrogen is generally given out and a little tin dissolved, but this is owing to the admixture of a portion of sulphuret of tin, for if the residue is washed, no subsequent treatment with this acid produces any effect. It is in this resistance to the action of muriatic acid, that aurum musivum is particularly distinguished from the simple sulphuret and the more and less oxydated hydro-sulphurets of tin.

When aurum musivum is digested with a solution of potash and heated, it quietly dissolves and forms a green liquid, from which acids separate a yellow powder, which is the super-oxydated hydro-sulphuret, and not regenerated aurum musivum.

If mosaic gold is heated strongly in a close vessel, (that is, to as full a red heat as a glass retort will bear) it is entirely altered in its nature, a large quantity of sulphureous acid gas is given out, some sulphur sublimes, and the residue, which is nearly five-sixths of the whole, is a black brilliant metallic-looking mass, which appears to be chiefly sulphuret of tin. A strong heat therefore causes the

union of part, if not all, of the oxygen of the aurum musivum, with that portion of the sulphur which flies off as sulphureous acid. [2 *Aikin's Dict.* 430—433.

The old process is as follows. Take 12 ounces of tin: 7 ounces flour of sulphur: 6 ounces sal-ammoniac: 6 ounces mercury. Melt the tin, add the mercury to it. When cold, powder the amalgam, and triturate it accurately with the sulphur and sal-ammoniac. Put them in a matrass, set it in a sand bath, keep up a gentle fire for four or five hours, then encrease it, but not beyond the degree necessary to sublime the volatile parts, otherwise the aurum musivum will be partly melted and spoiled. If the fire be properly managed, these quantities will afford 1 ounce, 4 drams and 2 scruples of volatile liver of sulphur: 13 ounces, 2 drams of sublimed muriat of tin and cinnabar, and there will remain at the bottom of the matrass 16 ounces of aurum musivum.

Woolf says that the following proportions give 17 1-2 ounces instead of 16; viz. tin 12, sulphur 7, sal-ammoniac 3, and mercury 3.

Another recipe. (Woolf.) Saturate melted tin with sulphur, by throwing the sulphur in at three or four intervals. You may use one-third or one-fourth of sulphur by weight, but according to Proust, the tin will not take up more than about 15 per cent. Of this sulphurated tin, take 10 ounces and mix it with 16 ounces of corrosive sublimate. You must have a cover over the vessel in which you triturate them together. Put the mixture into a retort, or matrass, or large crucible, having another inverted over it and luted, with a hole in the top. Calcine with a moderate fire for 6 hours, then keep the retort red hot for three hours. This produces aurum musivum of superior quality. Indeed the *best* sort seems not to be obtained without using mercury or some pre-

paration of mercury; although not a particle enters into the composition of aurum mosaicum, which consists of 2-3 tin and 1-3 sulphur.

A good coloured aurum mosaicum may be thus produced. Saturate 8 ounces of melted tin with sulphur: pound it: mix it accurately with 5 ounces more of sulphur, and 4 ounces of sal-ammoniac: calcine it with the precautions above mentioned. (Woolf.)

The apparatus recommended by Woolf is the following. Take a large black lead crucible, number 60; bore a round hole in its bottom about three inches diameter, and saw off an inch of its upper edge. If it has a lip, get a round piece of burnt clay of an inch thick or rather more, to fit exactly into this edge. The composition used for making paving tiles, answers very well for this purpose. In order to make use of this apparatus, fit the round piece of burnt clay to the inner edge of the crucible, by means of some loam softened with glue, and dry it slowly. Then turn it upside down, and lay it in a proper furnace on two iron bars. The mixture for the aurum mosaicum is to be put in through the round hole at top, and then covered with an aludel (a wide pipe or tube open at both ends) and luted. This serves to collect the flours and sublimate that rises. The fire is to be made under and all round the crucible. 1 1lb. troy of aurum musivum may be thus made at a time. The operation, which takes about eight hours, cannot fail, if the fire be of sufficient strength and of an equal degree from the top to the bottom of the crucible.

Mr. Woolf observes, that the sublimed muriat of tin produced in this process, is very far superior as a mordant to any of the solutions used by the dyers.

Mr. Proust has recorded 21 experiments on this subject in the 13th vol. of the Annales de Chymie. These experiments lead to the conclusion that aurum musivum

is the calx or oxyd of tin intimately combined with sulphur, in the proportion of 3 parts of tin to 2 of sulphur. Like Woolf, Proust found the process in which mercury or some of its combinations was employed, afforded the finest coloured aurum musivum. Thus from subliming equal parts of tin saturated with sulphur, and of corrosive sublimate, he obtained from 3 ounces of each, 2 1-2 oz. of very fine aurum musivum.

It results from these accounts that for the finest aurum musivum one or other of the following processes are expedient.

Tin 12 parts, sulphur 7, sal-ammoniac 3, mercury 3, as indicated by Woolf. Or

Equal parts of sulphurated tin and corrosive sublimate, ground together and sublimed: though from the mercury coming over in part revived, I should almost suspect, that the corrosive sublimate might be still further diminished.

For common aurum musivum, take the following proportions, viz.

Sulphurated tin 6 parts: sal-ammoniac 4 parts: sulphur 4 parts.

The fire must not be greater than enough to sublime the sal-ammoniac: steady and moderate at first, and then heightened to a red heat, but not a full red heat. If the heat should not be enough, as may be seen on opening the crucible, it may be further applied. Aurum musivum is no longer used as a medicine, but only as a colouring material in decorations.

The observations of Woolf as to the superiority of the sublimed muriat of tin as a mordant, deserves to be noted; for the dying of scarlet is becoming of consequence in this country. But it requires to be verified by experiment.

Aurum musivum is one of the ingredients in making the imitations of the beautiful stones, Aranturine and Lapis Lazuli: though I think its place may be supplied by ground gold leaf.

On the solution of Tin used as the composition for the Scarlet Dye.

I shall have to treat on this dye when I come to the article dying; but the observations I have to make on tin and its solutions, may properly find place here.

The usual composition, or mordant for the scarlet dye on woollen cloth is this. To one pound of the strongest aqua fortis add an equal measure of water in a glass vessel. Then bruise separately one ounce and a half of clean sal-ammoniac, and half an ounce of salt petre, and gradually dissolve these in the diluted aqua fortis in a cool place. Then add by a small piece at a time from two ounces to two ounces and a half of grain tin, previously granulated by being melted, and poured through a bundle of twigs or a birch broom, into water. The solution ought to occupy two days.

The aqua fortis ought to be of the specific gravity 1,5 or to weigh one half more than an equal bulk of water. Some good dyers, add only one ounce of sal-ammoniac, and two ounces of tin, to the pound of aqua fortis: but I shall prefer one ounce and a half of the salt, and two ozs. and a half of tin; because there is some reason to believe it will keep better. The sal-ammoniac prevents the oxydation of the tin.

I shall have a good deal to say on the scarlet dye when I come to that article, but at present I confine my observations, 1st. To the tin. 2ly. To the acid. 3ly. To the sal-ammoniac. 4ly. To the nitre. 5ly. To the water.

1st. Of the tin. The common tin frequently contains lead; and sometimes copper; with this admixture, no fine scarlet can be procured. Both lead and copper alter the crimson and the scarlet tinge; the latter metal saddens the colour. But, out of eighty grains of common tin from an ingot such as are usually sold in Philadelphia, I procured neither lead or copper. I dissolved it in nitric acid, which calcined all the tin: the oxyd being washed, shewed no trace of lead with sulphuric acid.

No tin is so fit for the purpose as that called the grain tin, and even that is not always free from contamination.

2ly. Of the acid. A scarlet dyer ought to make his own aqua fortis in glass. In the common way of manufacturing this acid, if iron stills or retorts are not used, iron heads to the stills, are. Hence, it is scarcely possible that the acid should not be contaminated with iron. This can be ascertained by tincture of galls, or prussiat of potash; and though the triple nature of this last salt is liable to objection, it will sufficiently answer the purpose.

Nitric acid is also contaminated by an admixture of muriatic; owing to the common salt contained in common salt petre; and also of sulphuric acid, owing to the impurity of the oil of vitriol usually employed, which comes over in the form of sulphurous acid gas. But I do not know that these are very objectionable in the process. The addition of nitre tends to saturate the superfluous sulphuric acid.

3ly. Of the sal-ammoniac. This salt is made according to modern processes, from alkali procured by the distillation of animal substances in long cylindrical iron retorts. It ought to be previously examined for iron, which uniformly gives a violet tinge to the cochineal colour.

4ly. Of the nitre. I do not think it worth while to purify this salt. The common impurities, except iron, do no damage.

5ly. Of the water. This is very important. All dirt, makes the colour dull. All the earthy salts sadden the colour. If it contain iron, it will give the violet tinge. It is indispensible to ascertain what iron it contains, and by evaporation of a quart of it, how much and what earthy salts it holds in solution.

Hence, the making of the tin mordant for scarlet cloth, as well as the necessary examination of all the other ingredients requires chemical knowledge to proceed with any degree of certainty. By and by it will be worth while for some chemist in this country to make the composition as an article for sale.

Common salt is not so good a vehicle of the tin as sal-ammoniac.

Filings of tin are given as a medicine in cases of worms: but I do not know of any further use of this metal. The smoking liquor of Libavius is not of importance as yet in a manufacturing point of view.

GEOLOGY.

Outline of Geology, by the Editor.

Before I enter on the relative ages of metallic substances, it may not be amiss to give a brief sketch of the formation of the earth, according to the best acknowledged facts we possess, and the most probable opinions hitherto advanced. In doing this, I shall not scruple to blend my own views of the subject, with the remarks which I shall be induced to adopt from other writers, chiefly Werner, as exhibited by Jamieson; confining myself however, as well as I can, to fair deductions from known phenomena.

There are only two systems relating to the explanation of the general appearance of our planet, that are entitled to any consideration: the one the *Neptunian*, at the head of which is Werner the professor of mineralogy at Friburgh; the other the *Plutonian*, advanced by the late Dr. Hutton, so well known in the mathematical world, and at present chiefly supported by professor Playfair of Edinburgh.

Werner's system, in brief, is, that all the more extensive and universally-found strata, or formations, of our globe, have been formed, partly by crystallization of substances dissolved or intimately mixed with the watery fluid that contained them in a chaotic state—partly by subsidence of the particles mixed with the water—and in cases of volcanic strata, by volcanic eruptions. His general distinction of primitive, transition, secondary, alluvial, and volcanic soils or rocks, appears to me too probable to be rejected; nor is it possible for any person who has seen, (as may very commonly be seen,) granite and quartz; also plants and soft shells, surrounded by and enveloped in, limestone, flint, siliceous grit, and argillo-silite, to doubt, but the great majority of rocks and stones, are formed by crystallization and subsidence of particles dissolved or mixt in water.

According to the Plutonian hypothesis of Hutton and Playfair, our globe is subject to a gradual but perpetual change, inducing endless alterations of continent and of sea, in the same places. The present continents, for instance, are subject to destruction by the action of air, rain, mechanical attrition, chemical decomposition, the operation of gravity, &c. The materials thus broken down, and decomposed, are gradually carried to the bottom of the ocean, where they are subject to induration by the action of internal heat, and new strata are formed, which in time are raised by subterraneous fires, becom-

ing in their turn terra firma. The sea is propelled over the old continents, which then become the bottom of the ocean, while the new continents are gradually clothed with vegetables and animals, and in process of time undergo the same gradual action, decay, and submersion, which their predecessors experienced.

The experiments of Sir James Hall, on the effects of heat modified by compression, have been made in pursuance and support of Hutton's theory; and he has certainly shewn, that crystallized forms of carbonat of lime may be produced under the joint operation of great heat and great compression, which are very similar to such as would be generally ascribed to a crystallization from watery fusion or admixture.

The view of the subject that at present occurs to me as most probable, is this:

The density of the earth, according to the calculations and observations of Sir Isaac Newton, Dr. Maskelyne, Dr. Hutton, Professor Playfair, and the honourable Mr. Cavendish, cannot be less than five times that of water.

The strata or formations of the earth, so far as they have been examined, consist of the following nine earths or their combinations: alumina, silica, calcia, magnesia, baryta, strontia, glucina, zirconia, yttria. The three last are found in quantities so comparatively small, as not to be worth notice on the present occasion. The same observation may be made, though in a less degree, on baryta and strontia, which are only found occasionally in secondary strata in nodules, or as the matrix of ores, or otherwise insulated. The earth and its formations may therefore be considered as consisting of alumina, silica, calcia, and magnesia, and their admixtures and combinations; interspersed rather than intersected occasionally by metallic substances.

Alumina has the specific gravity 2, calcia, 2.3, magnesia 2.3, silica 2.65. The metallic ores contained in these formations, are too few in number and in quantity to raise the specific gravity of the mass ,1. Add to this, that the quantity of sea & river water contained in these formations will greatly reduce the specific gravity of the mass; so that the average specific gravity of all the known strata of the earth cannot fairly be considered as amounting to more than 2; but if taken at 2.5, then will the known strata possess a specific gravity of one half the specific gravity of the whole globe. Hence it will follow, that this earth consists of a nucleus, of a metallic nature, whose specific gravity *exceeds* 5, covered by a crust consisting of a series of formations having together a specific gravity not quite reaching 2.5.

This outward crust, including the rivers and oceans that rest upon and within it, seems to be the only object of examination to the Geologist, or as the German philosophers affect to say, the Geognost. No observation that I know of, has hitherto extended beyond the granite formation that appears as its substratum. I know of no volcanic ejection that will warrant us in concluding that the matter thrown out, is any other than part of the formations that constitute this crust. The following questions admit but of conjectures.

What are the constituent parts of the nucleus?

Is there any series of cavities between the nucleus and the crust?

What is the thickness of the crust?

Of how many original and universal strata, or formations does this crust consist?

I tread upon new ground; but I use the aids which wise men have furnished; I have none of my own.

The nucleus is metallic: I conclude this, from its specific gravity; far too great for any known earth. Sir Isaac

Newton computed it at 7, but I abide by Dr. Maskelyne and Mr. Cavendish. If, according to them, the whole mass of the earth be 5, the nucleus cannot be less than 6, considering the deductions to be made for the various earths forming the crust, the waters that cover so large a part of it, and the cavities that are most probably contained in it.

Of what metallic substance? Probably of iron and nickel: because these are the only magnetic metals; and I know not how possibly to account for the phenomena of magnetism, but by means of a magnetic nucleus. Moreover, I cannot but suspect that some connection exists between the composition of meteorolites, all of which contain iron and nickel, and the subject of this investigation. The specific gravity of metallic nickel is only 8.38, of iron 7.6 or 7.7. The nucleus however will more probably consist of the ores of these metals than the metals themselves: and we know that very many of the iron ores are magnetic and polar. These are conjectures: but the present state of our knowledge does not afford better.

Are there any cavities intervening between the nucleus and the crust? Cavities which admit of the entrance of atmospheric air?

It should appear that there are such. For,

It is manifest that the whole series of formations from the uppermost alluvial soil down to the lowest granite, have in many instances been shaken en masse, from their foundations—upheaved. None of them are horizontal, as they were originally; a fact which Saussure first established: nor do any of them preserve an uniform dip or inclination. Marks of the revolutions they have undergone ab imo, from the very deep, are not to be gainsaid. The lowest and deepest granite, is most generally found also as the outgoing, or as constituting the summit of the

highest mountains—breaking out to the day, in the well chosen phraseology of the miners. Nor is the older granite always in its original situation, undermost: it is found sometimes overlaying gneiss and other primitive strata. Evidently the result of eruptions: taking place, not in cavities that occur in or between the layers of the crust, but below them all; for they have all been raised up from the lowest granite, with its superincumbent formations by some deep seated and mighty force.

Will it not be allowed, that this force is probably volcanic? Whence otherwise is it to be derived?

Electrical earthquakes have had their day: they will occur no more. Nor shall we imitate (I suspect) the Neapolitan philosopher who proposed to sink wells to let out the steam of the great abyss. I venture to assert it, as a theory at least as likely as any other hitherto proposed, that volcanoes and earthquakes, are owing to the chemical action on each other, of iron, sulphur, moisture and atmospheric air. Where are these to be found?

All the sulphur of Europe, is supplied by the sublimation of that substance in the Solfaterras—in the immediate vicinity of European volcanoes.

All lavas contain (on the average) 24 per cent. of iron. I think this is the quantity which Kirwan states.

We have then as volcanic products, sulphur and iron; and if through the lower strata or formations, water should be supplied, we have even without atmospheric air, all the materials for earthquakes, volcanoes, eruptions and subversions. The water is decomposed: the iron and sulphur oxygenated: caloric evolved: hydrogen escaping through immense cavities inflamed, and all the phenomena at once accounted for.

Having now arrived, *per varios casus, per tot discrimina rerum*, from the nucleus to the crust of the earth, we will

try what is to be done with that important part of our subject.

The following circumstances have been observed, and may be taken as facts. 1. There appears to be a series of strata, or as Werner calls them formations, that may be considered as surrounding the nucleus of the earth. The first formed, or lowest series, always preserve the same situation to each other except where occasional eruptions, or circumstances not of a general nature, make a variety in their situations. These strata are not only the deepest, but they are also the highest that are observed in the crust of the earth; forming the tops of the highest mountains. They are characterised by an appearance of crystallization, and by containing no remains of organic matter, vegetable or animal. The strata or formations that in general constitute this first, deepest, highest, and crystallized series, are,

Granite, consisting of feldspar crystallized in facets frequently lustrous; quartz; mica. Sometimes also schorl. Sometimes the schorl, sometimes the mica, sometimes both are wanting. But these are accidental deficiencies. This stone in all its varieties, is common about Baltimore, and at Germantown.

Gneiss.—This is a stone composed of feldspar, quartz, and mica, in much smaller particles than in granite; in the mass, it is also stratified or formed in layers, which granite is not. This is the common stone used for building, and for kirb stones in Philadelphia.

Mica Slate.—This is a stratum or formation consisting principally of quartz and mica, in which the mica predominates. It generally also contains crystallized garnets. Stones of this formation are common about Germantown, the Falls of Schuylkill, &c.

Clay Slate.—The common grey, bluish, yellowish, or smoke coloured slate, often used for covering houses.

Primitive Trap.—This is the pure black hornblende, the hornblende slate, and the mixed hornblende; it appears at 11 and 12 miles from Philadelphia on the Chesnut Hill road immediately after the steatite or soap stone; and intermingling with the micaceous shistose limestone, and then with the granular limestone.

Granular Limestone.—Crystallized: this may be observed on the road to White Marsh, about 13 miles from Philadelphia: the mica slate, becomes gradually micaceous limestone slate, and then granular limestone or marble, coloured with hornblende (amphibole, primitive trap) as in the black, and black and white marble of White Marsh used at Philadelphia. The clay slate here, does not intervene so far as I recollect.

Serpentine.—I have not traced this in the neighbourhood of Philadelphia: the soap stone first appears. This I think passes into serpentine, of which the neighbourhood of Easton furnishes fine specimens. Chlorite escaped me.

Porphyry and Sienite.—Porphyry, is compact feldspar, containing small crystals of feldspar: or quartzose stones containing such small crystals. Sienite, is a stone composed of feldspar, quartz and hornblende. I suspect this formation has not been traced upon, or over lying the serpentine in Pennsylvania. These stones abound, as rolled specimens out of place, on the shores of the North East branch of the Susquehanna from Danville upward to Wilkesbarre, and I believe at intervals as far as Tioga point. I know not the source of them. I suspect them to belong to the secondary trap formations, for they are intermixed with all the varieties of green stone. The feldspar is generally reddish.

Sometimes a second deposition of granite, or newer, more recently deposited granite, is found among the primitive strata: in this the crystals are similar to those of

the oldest granite formations, but smaller. If I mistake not, Norristown will afford specimens of this.

These strata or formations are so generally found, and in the same situations as incumbent upon or subtending each other relatively, that they may be considered as universal.

Their crystallized appearance shews that their particles have been either dissolved or very finely suspended in water, so that the attraction of crystallization has been free to operate: that this water has been deep, so as that the lowermost parts of it have not been much agitated during the crystallization, which would otherwise have been more confused than it is: and indeed the oldest formations are the best crystallized. A part of the water covering the nucleus must have been taken up as water of crystallization, in the primitive formations. Again! when these were deposited, there were no vegetables formed: of course no animals: nay even the sea was unpeopled, for there is no trace of any organic remains in these strata. Even the Belemnites, the Asteriæ, the Echini, the Entrochi, the most simple forms of oceanic animal life, do not occur till the transition strata appear. Hence the propriety of denominating these formations, *primitive.*

By processes of nature, (beside the consumption of water by the new crystallized masses) to us unknown, the mass of waters appear to have diminished. The higher parts of the primitive strata or formations became the shores to the water superincumbent on their bases and middle regions; the simplest forms of oceanic animals came into existence, and mosses and lichens of high latitude, would generally occupy the surface of the primitive strata, gradually decomposed by the alternate action of air and water after many ages.

During this period, while the strata were in a state of *transition* from the chaotic to the habitable state, other

deposits would gradually be made from the waters, now decreased in quantity; and take their place below the summits of the primitive range. Those summits being exposed to the action of the atmosphere, of rains, of frost probably, and to the action also of the waters with their contents still incumbent on the earliest strata, would furnish masses and particles washed away, which would mingle with the deposits of the transition series: this series therefore, will exhibit appearances of mechanical and chemical intermixture of earths and stones such as are found in the green stone, siliceous hornblende rock, argillaceous hornblende rock, grauwacky, and lastly, wacky which form the trap rocks of the transition series. Specimens of these trap formations can be traced from Perkiomen Bridge, through Reading to the mountain ranges of shistus that reach from Putt's forge to Sunbury, in Pennsylvania. The transition limestone is the earliest of this series, but I have not had occasion to remark the flint slate or the transition gypsum. During the period when these transition formations were deposited, there would be no land animals, for there would be no vegetables for them to feed upon. There would be no vegetables, unless some few lichens, mosses, or ericas, that would find foothold upon the slight decomposition that after the lapse of some ages would take place on the surface of the primitive rocks. The sea only would be peopled, and that but sparingly; for in that mass of muddy water, none but the lowest and most inferior grades of animal life, and such as do not inhabit deep water could exist. Hence we find the transition formations contain in their substances, some belemnites, asteriæ, entrochi, echini, &c. but no organized vegetable substance except very rarely in the latest rocks of this series, and no remains whatever of terrestrial animals.

Indeed, in the high latitudes of the outgoings or summits of the primitive strata, very few vegetables even at the present day can live. No vegetation fit for animal life, could take place, until the transition, and most of the next series of (secondary or fletz) formations had subsided. These would occupy gradually lower and lower situations, till a rich soil from every kind of intermixture of earth mechanically deposited, would afford a proper temperature of region, and an easily decomposed soil wherein vegetables could grow.

Next to the transition series, then, come the *secondary* or as the German mineralogists call them, the Floetz (Fletz) Rocks: so called, because they appear to be more floated or horizontal; though I confess the appellation does not appear to me peculiarly appropriate.

These strata, consist principally of sandstone, limestone, sometimes stinking from bituminous impregnation, sometimes shelly; secondary trap, graphite and bituminous coal, gypsum, rock salt.

The old red sandstone, limestone, secondary trap, and newer sandstone, are to be found in Adams and York counties. The graphite or *anthracite coal formation** in Pennsylvania, extends from the Delaware at the heads of Lacawana and Lehigh to the North mountain, whose southern base I think it subtends. It is found ten miles all round Wilkesbarre; it is found on the Berwick turnpike road; it is found a mile from the turnpike road 21 miles from Sunbury toward Reading; it is found on the Susquehanna, or within a few hundred yards of it, six miles below Sunbury; it is found at the iron works on the waters of the Schuylkill, on the road from Reading to Hamburgh†. This stratum does not extend westward beyond the west branch of Susquehanna. I do not know whether it is connected or not with the anthracite of

* Carbon with little sulphur and no bitumen.

† And in Mahantongo $8\frac{1}{2}$ miles from Susquehanna.

Rhode Island, not having been there. But this last seems to border on primitive formations, under circumstances, which for want of knowledge, I cannot explain.

The *bituminous coal formation* in Pennsylvania, exhibits its first trace as breaking out to the day, on the Juniata. The bed of the river at Chingleclamoose, up the west branch of Susquehanna, is bituminous coal. It extends from thence northward and westward throughout the whole of Pennsylvania. How far it extends on the Monongahela, Alleghany, and Ohio, I cannot say. The shell limestone extends up Sugar creek on the west side of the north east branch of Susqa. toward the heads of that creek, where it abounds so much in shells as to be fit for lime. All the stones about the Sheshequin abound in shells. This stratum I have traced downward (south westward) through Buffalo to Jacks' mountain, which is a mass of shell lime and calcareous Breccia. How far it extends in both directions I know not.

I have observed that the Alpine heights of the primitive mountains could at no time furnish much vegetable food. The same remark, but in a less degree, will apply to the transition range. The low and kindly climates occupied by the secondary series—the soft and decomposable nature of these depositions would furnish the true theatre of vegetable life: and until these regions were filled with vegetables, the race of animals could not have been produced; for on what could they subsist? Gramenivorous animals therefore must have succeeded the various forms of vegetable existence, and carnivorous the gramenivorous.

The vegetable matter imbedded in the substance of the secondary strata, will consist of the remains of vegetables that grow on the transition strata; and the animal remains will consist chiefly of such animals as were produced in early stages of animal existence, particularly the smaller

aquatic animals; and of these, chiefly shell fish, as shells are not so soon decomposed as mere animal substance.

Coal and bituminous substances, will also occur in the latter floetz or secondary formations only; for with me there is no doubt of these being the produce of submerged vegetables, subjected to the effects of heat modified by compression. The many specimens I have seen at Whitehaven and elsewhere in England, and some American specimens that I possess myself, wherein there is an evident gradation and passage from wood to coal in the same piece, compels me to adopt this opinion. The process of nature in converting wood into coal, I do not pretend to have satisfied myself about.

The latest deposits of what is considered as the secondary series of formations, will comprehend basalt, wacke, greystone, amygdaloid, newer limestone, chalk and calk sinter, obsidian, pumice, pitch stone,* (I have found this among primitive rocks at the mills near Baltimore) coal, gypsum and rock salt, which two last usually keep company in this series; argillaceous iron ore, petrifactions, &c.

The remains of land animals are nearly confined to the newest floetz and alluvial deposits. The remains of many land animals, have been found, particularly by Cuvier, of which the race does not now exist. So La Marck has found remains of aquatic animals similarly circumstanced. The same remark will apply also to vegetable remains.

It is evident that the newest of each series of formations will touch upon, and in some degree intermingle with the oldest of the succeeding series, and partake in some degree of the mutual characters.

As the waters gradually decreased, and retired into their oceanic basons, the finer kinds of earthy matter would subside the last: and those saline substances that

* I doubt about Pitch stone belonging to this series.

could no longer find fluid to hold them in solution, would crystallize.

These last are *alluvial* deposits; which also are sufficiently general to merit the title of formations, although varying in their composition perpetually, as clay, loam, marle, bog ore, sand, gravel, peat, &c. and their combinations. These occupy the lowest levels and the bases of the other rocks.

Beside these, occasionally we meet with *volcanic* rocks or stones; lavas. These contain debris or broken fragments of many deep formations, as the granite, mica slate, greenstone, hornblende, and sandstone found in ejected granular or primitive limestone. Hence some volcanic caverns are probably situated between the nucleus and the primitive strata: a situation which we are led to presume, from the inclination or dip of the oldest formations: their position would naturally have been level and horizontal, had not some mighty force raised them from their base. What effect the influence of the moon has had, in determining the circumstances of these earthy depositions out of the immense body of water that in their chaotic state contained them, no one now can fully explain: that it must have produced oceanic tides then, as well as now, perpetually varying, with the varying density of the mass of turbid fluid acted upon, we can hardly doubt. It is evident also that many ages must have passed before the surface of our globe, put off its chaotic state, and became fit for the habitation of man. The *general* system, of which I have presented a scanty outline, seems pointed out in most of its parts, by facts and appearances not to be denied, or by other theories so well explained: but as to all the *particulars*, doubts and uncertainties hang over them, which more accurate and future observations may in some degree serve to explain.

I have said nothing about the metallurgy of the formations, meaning this as a mere introduction to the following extract from Jameson, on the respective ages of the various metals and their ores.

RELATIVE AGE OF METALS.—JAMESON.

1. *Molybdena* appears to be the oldest of all the metals. It occurs imbedded, in six-sided tables, in granite of the oldest formation, in the mountains of Silesia, those of Sweden, and it is said also in the primitive granite of Cruachan in this country. It also occurs, along with tinstone, woolfram and tungsten, in the Saxon and Bohemian tin formation. That formation lies in granite, which from its characters, appears to belong to the newest granite formation. This metal is also found in the famous iron-mines of Norway; but we know so little of the geognostic relations of the rocks in these districts, that we cannot as yet determine with any certainty the exact date of the molybdena they contain. In Glenelg, I observed very small portions of it imbedded in chlorite-slate. Combined with oxygen, it occurs in small quantity in the form of molybdat of lead (yellow lead ore), in the oldest flœtz-limestone.

2. *Menachine*, the Titanium of chemists. This metal appears to be next in age to molybdena, because one of its species, Rutile,* occurs in those drusy cavities which are not unfrequent in granite mountains of the highest antiquity, lying in or upon the rock-crystal, adularia, and foliated chlorite, with which these cavities are lined. The same species occurs also imbedded in mica-slate and sienite. Dr. Reuss, the Bohemian mineralogist, affirms that he observed it in the newest flœtz-trap formation, imbedded in basalt; and this observation is strengthened

* Frequent in Virginia.

by the discovery of Mr. Gregor, who found menachine to be a constituent part of basalt.

We shall now mention particularly the age of the different species of the Menachine genus.

a. Rutile is found in Hungary, Switzerland, and Russia. The Hungarian varieties are usually imbedded in mica-slate; the Russian are generally accompanied with or included in rock-crystal, and those found at St. Gothard are accompanied with rock-crystal, felspar, and other fossils.

b. Octahedrite, another species of menachine, occurs in very old veins that traverse gneiss and mica-slate. These veins are composed of felspar, axinite, iron-mica, rock-crystal, chlorite, and sometimes mica. It has been hitherto found only in Dauphiny.

c. Rutilite.—The late Dr. Mitchell, in his excellent Memoir on Menachine, in the last volume of the Irish Transactions, has the following account of the geognostic situation of *rutilite:* "In the mountains of Passau, this fossil is found imbedded in a coarse granular aggregate of felspar and hornblende, and felspar and actynolite; therefore belonging to the genus Greenstone, and order of Primitive Trap. In Norway, it occurs in rocks belonging to the same formation in which the celebrated beds of magnetic ironstone lie, and is associated with hornblende, and several other individuals of a tribe not as yet sufficiently examined and described, but which evidently constitute middle links between actynolite and hornblende, and to which the names Acanticone and Arendalite have been applied. Near Dresden and Brun, it is found dispersed through sienite, and at Galway, in Ireland, in an uncommonly beautiful porphyritic sienite. Hence it appears that this fossil has only occurred in rocks belonging to primitive trap, or in sienite, the last crystallization

which took place within the primitive period, and must therefore be considered as a later production than rutile. Here a consideration of the laws of crystallization countenances the observations on the order in which primitive rocks follow one another. The rutile, consisting of few and simple elements, of cotemporary origin with a granite, in which rock-crystal occupies the place of quartz, and adularia that of common felspar, sufficiently bespeaks a period, when the solution, being purer and more tranquil, furnished an earlier and purer crop of crystals; while the confused and irregular crystallization of primitive trap and sienite, together with the greater impurity of the felspar, and very compounded nature of the hornblende and rutilite, indicate an inferior purity of the solution, and consequently later precipitation of the crystallized mass."

d. Nigrine.—This species has been hitherto found only at Ohlàpian in Transylvania, in alluvial hills, consisting of yellow sand, intermixed with fragments and boulders of granite, gneiss, and mica-slate, and from which gold is obtained by washing. This gold is the purest found in Transylvania; a circumstance sufficiently indicating, that it belongs to a different, and consequently earlier formation, than the usual Transylvanian native gold, which occurs there in clay-porphyry, grey-wacke, and grey-wacke slate, and belongs to the brass-yellow variety, from the considerable alloy of silver which it contains. In these stream-works, the nigrine is obtained at the same time with the gold, and comes to us intermixed with grains of rutile, precious garnet, kyanite, and common sand; which renders it extremely probable, as Dr. Mitchel remarks, that this fossil, also, is a native of primitive mountains.*

* Vide Mitchell, in Irish Transactions.

e. Iserine.—Hitherto this fossil has been found only in the high Riesen mountains, which separate Silesia from Bohemia, near the origin of the Iser, dispersed through the granitic sand which forms the bed of that river. To what order of rocks it owes its origin, is uncertain; but its near affinity to iron-sand, which is exclusively an inmate of the newest flœtz-trap formation; and the certainty that this formation was formerly superstratified, at a great elevation, on the Riesen mountains, (as the remains which form the Buchberg, and occupy the Schneegruben, sufficiently testify,) renders it highly probable, that this fossil also may belong to that formation; and consequently dates its origin from a much more recent period than the foregoing species of this genus.*

3. *Tin.*—This metal appears to be next in age to menachine. It is sometimes of nearly cotemporaneous origin with old primitive rocks. Thus it occurs in very old veins, that traverse granite, gneiss, mica-slate, and clay-slate. These veins contain, besides tin-stone, also wolfram, tungsten, molybdena, iron-glance, arsenic-pyrites, copper-pyrites, topaz, quartz, mica, chlorite, apatite, fluorspar, steatite, and lithomarge. The veins that traverse clay-slate are accompanied with schorl, and appear to belong to a different formation from those veins that occur in mica-slate, gneiss, or granite.

It occurs also disseminated through granite, and in beds that alternate with strata of granite. This granite, however, appears to belong to the newest formation.

4. *Scheele.*—The two ores of this metal, viz. Wolfram and Tungsten, are of equal antiquity with tin. *Wolfram* occurs almost always in veins in primitive mountains, along with tin-stone; and sometimes, although rarely, in veins in transition mountains. It appears in all

* Mitchell, Irish Transactions.

the tin-stone formations, excepting that which contains schorl. In these situations, it is found in England, Saxony, Bohemia, and probably also France. In the Hartz, it occurs without tin-stone, in great veins, that traverse grey-wacke; constituting, however, but a small portion of these veins. It never occurs in newer rocks; and the instance we have just mentioned, of it occurring in grey-wacke, is only an exception to the rule, that wolfram is a very old formation of the primitive period.

Tungsten, the other ore of scheele, occurs only in primitive mountains, and in different tin formations. This is the case at least in Saxony, where it is found in most considerable quantity. The geognostic situation of that found in Sweden is unknown. Like wolfram, it does not occur in that particular tin formation which is accompanied with schorl.

5. *Cerium.*—This metal occurs imbedded in wolfram; hence is of equal antiquity.

6. *Tantalum.*—This appears also to be a very old metal. It is nearly allied to tin. Its geognostic situation has not hitherto been ascertained with perfect accuracy. It would appear to occur in felspar-veins that traverse old mica-slate; hence it is to be considered as of cotemporaneous formation with it. One species, the Tantalite, occurs in the parish of Kimito in Finland; the other, the Yttertantalite, at Ytterby in Sweden. We may remark, however, that the geognostic situation of the Yttertantalite is not well known; the geognostic situation just mentioned is that of the tantalite.

7. *Uran.*—This metal occurs only in primitive mountains. Pitch-ore, uran-ochre and uran-mica, occur together in veins of a pretty old formation that traverse gneiss; but uran-mica occurs principally in ironstone-veins that traverse granite and other primitive rocks.

8. *Chrome.*—Needle-ore and chrome-ochre are the only ores of this metal hitherto described. These occur imbedded in common quartz, accompanied with lead-glance, different ores of copper, and traces of native gold, all intimately aggregated together. Hence it is probable, that these ores occur in a bed in primitive rocks. Chrome, however, colours several fossils, whose relative age is better known. Thus it gives the beautiful green colour to the emerald of Peru, which occurs in clay-slate; the deep blood-red colour to the pyrope, an inmate of the second serpentine formation, and wacke; the beautiful series of red colours to the oriental ruby, which is conjectured to occur in the newest flœtz-trap formation, and probably in certain primitive rocks; the aurora-red colour to the red-lead of Siberia, whose geognostic situation, however, is but imperfectly known; and, lastly, the green colour to serpentine, and the red colour to spinelle.*

9. *Bismuth.*—This metal occurs in veins that traverse gneiss and mica-slate, and is accompanied with cobalt and silver ores.

10. *a. Native arsenic*,—occurs almost always in primitive mountains, and most frequently in veins, excepting a small portion that appears in beds in the Bannat of Temeswar.

b. Arsenic pyrites,—which is a combination of arsenic, iron and sulphur, occurs in beds in mica-slate at Reichenstein in Silesia; and in a similar repository in the newer granite of Zinnwald. It occurs also in veins that traverse gneiss; as in the vicinity of Freyberg, in the electorate of Saxony, where it is highly characteristic for certain metalliferous formations; in veins that traverse clay-slate, as in the Saxon Erzgebirge, and in veins that traverse

* This metal, with iron, manganese, and nickel, occurs in aerolites, those stones that fall periodically, and in the direction of the magnetic meridian, from the atmosphere.

Chrome combined with iron occurs in the steatite of the vicinity of Philadelphia and Baltimore. T. C.

grey-wacke in the Hartz. It is even sometimes disseminated through the newer porphyry and serpentine.

c. Yellow orpiment—seems to occur only in flœtz-rocks; whereas *red orpiment* appears to be confined principally to primitive rocks.

d. Pharmacolite, or arsenic-bloom, (Arseniate of Lime of chemists,) occurs in veins that traverse granite in Furstenberg; gneiss and mica-slate in Saxony, and grey-wacke in other countries. In Hungary, it occurs along with yellow orpiment; hence it is there probably of newer formation.

11. *Cobalt.*—*Cobalt-glance* is the oldest species of cobalt-ore. It occurs, in beds, in mica-slate, and does not appear in any of the newer rocks.

b. Grey Cobalt-ore occurs in veins that traverse granite, gneiss, and clay-slate.

c. White Cobalt-ore occurs more frequently than any other species of the cobalt family, and also in a greater variety of geognostic relations. It occurs in beds and veins; of the latter, two formations are known; one that occurs in primitive, the other in flœtz mountains. It occurs also in considerable quantity in transition-mountains. The veins in primitive mountains, traverse granite, gneiss, mica-slate, and clay-slate. The newer formation occurs in veins, that traverse the oldest flœtz-limestone.

12. *Nickel.*—This metal occurs both in primitive and flœtz mountains, and also in small portions in transition-mountains. In primitive mountains, it is accompanied with silver-ores; in transition-mountains, with lead-ores; and in flœtz-mountains, with copper-ores. In all these classes of rocks, it occurs in veins.

13. *Silver.*—This metal occurs in primitive, transition, and flœtz-mountains; but it would appear, that the greatest variety and quantity of native silver, and true ores of silver, occurs in primitive mountains. We shall,

as illustrative of the age of this important metal, mention that of native silver, and several of the most important ores.

a. Native Silver.—It occurs, with the exception of slight traces in the well-known *corn-ears* of Hessia, in flœtz-mountains, always in veins that traverse primitive and transition mountains. It appears in veins that traverse granite in Suabia, and sometimes in Saxony; in veins that traverse gneiss and mica-slate in Saxony, Bohemia, and Norway; in veins that traverse clay-slate in Saxony and Bohemia; and, lastly, in veins that traverse porphyry and sienite, in Saxony and Hungary. The age of the rock, however, does not always correspond to that of the venigenous formation; thus, the veins in the granite of Furstenberg are newer than those in some of the varieties of Saxon gneiss. It occurs in very inconsiderable quantity in transition-mountains.

b. Antimonial Silver.—It occurs only in veins. In Wirtemberg, these veins traverse granite, and in the Hartz, grey-wacke; nevertheless, these formations do not differ much from each other.

c. Corneous Silver-ore, Muriat of Silver of chemists. This remarkable ore of silver occurs always in silver veins, but only in their upper part, and in such a position in regard to its accompanying minerals as shews that it is always the newest fossil of the vein in which it appears. These veins traverse granite, gneiss, mica-slate, and clay-slate.* It occurs only, in quantity, in Mexico and Peru: small portions have been observed in Saxony, Cornwall, Siberia, and other countries.†

* It is said to occur in flœtz-limestone in Peru.

† This ore particularly the conchoidal subspecies, has an icy or glassy aspect, and hence was denominated Vitreous or Glassy Silver-ore by older mineralogists. The vitreous silver-ore of Kir-

d. Silver-glance.—This is one of the most common and abundant of the silver-ores, and there are but few silver formations in which it does not occur in greater or less quantity. It occurs however, only in primitive mountains, and always in veins that principally traverse gneiss, mica-slate, and clay-slate, more seldom porphyry, and still more rarely granite.

e. Red Silver-ore.—This beautiful ore occurs in veins that traverse gneiss, porphyry, and grey-wacke.

f. White Silver-ore.—It occurs in veins that traverse gneiss, and it continues to the greatest depths in these veins.

g. Black Silver-ore.—It occurs in veins that traverse gneiss, porphyry, sienite, and grey-wacke.

General Remarks.—The ores of silver are in general accompanied with calcspar and heavy-spar; and from the preceding details, appear to occur principally in veins that traverse primitive and transition mountains. The greatest portion of the silver of commerce, however, is obtained from argentiferous lead-glance, an ore that occurs more abundantly in the flœtz than the primitive mountains; hence it is somewhat doubtful, whether or not silver may not be considered as a newer metal than its ores seem to intimate.

14. *Copper.*—This metal is more widely distributed, and occurs in a greater variety of formations, than any of the preceding. Thus, it occurs in small quantities in a native state, disseminated through the granite of Cornwall. The granite of that country, however appears to me, from the observations of Professor Playfair, to belong to the newest formation; hence this native copper cannot

wan and others, is silver-glance,—a mineral that does not possess the glassy aspect which so remarkably characterizes the conchoidal corneous silver-ore.

be considered as reaching to the oldest rock of the primitive class. The great quantities of native copper found in the mines on the eastern side of the Uralian mountains, and the masses in Brazil and Canada, originated from mica-slate, or more particularly from granular limestone that occurs in mica-slate; hence, if my conjecture respecting the granite of Cornwall be correct, these masses are of an older formation than the copper found in that granite. It occurs also in veins that traverse gneiss, mica-slate, clay-slate, and grey-wacke; and small portions have been noticed in serpentine-porphyry, and rocks belonging to the newest flœtz-trap formation.

a. Variegated Copper-ore, which is copper combined with sulphur and oxygen, occurs, in beds, in mica-slate at Rudolstadt in Silesia, Dognatska and Saska in the Bannat of Temeswar, and Roraas in Norway. It has also been observed in veins traversing gneiss, mica-slate, grey-wacke, and bituminous marl-slate.

b. Copper-Pyrites.—It occurs in all the great classes of rocks, and sometimes in veins, sometimes in beds; which latter are often of great thickness. The oldest formation of copper-pyrites, and indeed of copper in general, is that which occurs in beds in gneiss. It occurs also in beds in mica-slate, clay-slate, transition-rocks, and the oldest flœtz-limestone. Very small portions of this ore appear in still newer formations: it occurs also in veins in primitive, transition, and old flœtz-rocks, but is far more abundant in primitive than any of the other classes of rocks. As it is the principal ore of copper, it follows, that what we have stated respecting its age, is perfectly expressive of the age of copper in general.

15. *Gold.—Gold-yellow native gold* occurs in masses, or in the form of sand, in the beds of many rivers. It would appear, that this alluvial gold is not derived from beds or veins, but from rocks through which it has been

disseminated. We have no certain information respecting the geognostic situation of the Peruvian gold; but we have much to expect from HUMBOLDT on this curious and important subject. The age and geognostic relations of the gold-sand of Guinea and Brazil are equally unknown. If the views published by the Portuguese mineralogist DANDRADA be correct, it is probable, says KARSTEN, that the gold of Brazil will be found to occur in a sandstone somewhat older than the independent coal-formations.*

Brass-yellow native gold is confined to the newer porphyry and grey-wacke, where it occurs in veins, as in the case in Hungary and Transilvania. It is said also to occur in sandstone and bituminous wood. Veins of gold also occur in the Uralian mountains; and these appear to occur in old flœtz-limestone.

16. *Sylvan*, Tellurium of chemists.—This metal occurs along with brass-yellow native gold in the newer porphyry, and has been hitherto found only in Transilvania.

17. *Antimony*.—This metal is found in all the Hungarian and Transilvanian gold mines, and hence it occurs in newer porphyry and grey-wacke. The oldest formation occurs in beds with iron-pyrites and quartz at Schmolnitz in Hungary, and appears to be cotemporaneous with that found with green garnets in Norway. It occurs in veins that traverse grey-wacke in the county of Dumfries.

18. *Manganese*.—This metal occurs in veins in old primitive rocks, but most abundantly in numerous small veins that traverse the newer porphyry, and in veins that traverse grey-wacke. According to the late observations of Karsten, it occurs, along with beds of ironstone,

* Gold-yellow native gold has been found in veins along with quartz and iron-pyrites, but the age of these veins is not known.

in the period of the first flœtz-limestone. It probably also occurs in formations of a later date.

19. *Lead.*—This metal occurs in the state of lead-glance, in beds, in primitive mountains in the Bannat of Temeswar, but the quantity is so inconsiderable as not to entitle us to infer from this the high antiquity of lead. The beautiful crystallizations of white, green, yellow, and red lead-ores, are also insufficient for enabling us to ascertain this important point. It is lead-glance, the combination of lead and sulphur, that affords the clew for determining the age of lead. That ore as we have already mentioned, occurs in inconsiderable beds in the primitive mountains in the Bannat of Temeswar; in more considerable beds in the transition mountains of the Hartz; but the greatest accumulation appears to be in beds in the oldest flœtz-limestone. Thus, the extensive mines of Tarnowitz, between the Oder and the Vistula, in Upper Silesia, contain great beds of lead-glance in the oldest flœtz-limestone. In Carinthia there is another great deposition of the same kind; and at Zimapan, in New Spain, great beds of lead-glance also occur in the same limestone formation.

20. *Zinc.*—This metal almost invariably accompanies lead, and either in the form of blende or calamine. The lead-glance veins in primitive and transition mountains are always accompanied with blende; but the greatest quantity of this metal occurs in the state of Calamine, in great beds in the second flœtz-limestone, where it is also accompanied with lead-glance.* These beds of calamine occur in England, and extend through a considerable portion of Poland, Silesia, Westphalia, and the Netherlands.

* It has not been satisfactorily ascertained, whether these beds occur in the first or second flœtz-limestone.

21. *Mercury.*—This metal, in the form of cinnabar, occurs in beds and veins in primitive mountains, but in inconsiderable quantity; it is in the flœtz or newer rocks that it appears in abundance. In primitive mountains the beds lie in chlorite-slate, and the veins traverse rocks of the same kind: In flœtz-rocks the beds are accompanied with slate-clay and sandstone, and probably belong to the coal formation. The great mercury mines of Idria, that yield yearly upwards of sixty tons of mercury, are situated in this newer formation.

We have still two metals to consider, viz. Iron and Platina.

22. *Iron.*—It is the most universally distributed of all the metals. It forms a constituent part of the oldest granite. The Kasanar in Siberia, and the magnetic rocks near Dannemora in Sweden, prove that iron exists in great quantities even in the older primitive rocks. Combined with sulphur, as iron-pyrites, it occurs, in great beds, in gneiss, mica-slate, and hornblende-slate. Other iron-ores occur abundantly in transition rocks. The flœtz-rocks are also very abundant in iron: thus, the first or oldest flœtz-limestone contains great depositions of brown ironstone, as is the case at Sommo Rostro in Biscay, Huttenberg in Carinthia, and Tarnowitz in Upper Silesia. The same formation also includes a vast mass of sparry ironstone in Stiria, which has been worked to an immense extent, and with great profit, for 1200 years. The independent coal formation, which is supposed to be newer than flœtz-limestone, contains great accumulations of clay-ironstone. Clay-ironstone, and iron-sand, occur in the newest flœtz-trap formation; and, lastly, great depositions of bog iron-ore appear in the newest of all the classes of rocks, the Alluvial.

23. *Platina.*—This metal occurs only in grains along with gold and iron-sand, in the alluvial soil of the valleys

in South America. HUMBOLDT found a mass of platina, the size of a pigeon's egg, in the alluvial soil of the valley of Choco in South America, along with rolled pieces of porphyry-slate.*

The preceding details teach us,

1st, That metals differ very much as to the period of their formation.

2d, That the variety and quantity of metalliferous substances decrease in general from the primitive to the alluvial period of the earth's formation.

3d, That molybdena, menachine, tin, scheele, cerium, tantalum, uran, chrome, and bismuth, are metals of the oldest primitive formation, and that only feeble traces of them are to be observed in newer periods.

4th, That although arsenic, cobalt, nickel, silver, and copper, occur in old primitive mountains, they also extend to newer mountains.

5th, That gold, sylvan, antimony, and manganese, are metals of the middle age, occurring in the newer primitive, the transition, and the oldest flœtz-rocks.

6th, That lead, zinc, and mercury, are of a very late date, when compared with those metals we have already mentioned, because they occur in greatest quantity in the newer or flœtz formations.

7th, That iron is found in every rock, from the oldest granite to the newest alluvial deposit; hence is universally distributed, and is therefore a production of every period.

8th, That the more crystalline ores abound in the primitive mountains, but continue decreasing in quantity

* VAUQUELIN has lately discovered it in the silver-ores of Gaudalcanal in Spain. It is said also to have been found at Niznei Novogorod, six hundred German miles N. W. of Petersburgh. The truth of this report has been lately called in question.

and variety from the primitive rocks to the newest alluvial deposits. [3 *Jameson's Min.* 256—276.

Remarks by the Editor.

This account of the age of the various metals, I have inserted from a persuasion of its practical utility: as leading us to the strata or formations, wherein, according to the best observations, we may reasonably expect to find the kind of ore we are in search of. Hence the great importance of mineralogical as well as chemical knowledge, to assist in developing and employing the resources of a country that are as yet concealed in the bowels of the earth. The very foundation of British science and British power, is stone-coal and iron: nor is there a manufacturer of any eminence who has not received a chemical and many of them a mineralogical education. To be sure, this is a fashion of late years; that is within twenty; but does not the prodigious improvement, and overwhelming power of that country date its growth from the same period?

Let us consider for a moment the difference between two countries, the one of which manufactures, the other only purchases a piece of printed calico. The one a nation of shopkeepers and farmers—the other supplying from the stores of its own science and resources, the commodities that the other stands in need of. The shopkeeper needs nothing but his shelves and his counter; the farmer can manage all his concerns with the simple aid of a blacksmith and a wheelwright. Shew to these persons a piece of calico of three reds, chocolate, black, yellow, olive, green, and blue; they will stare at it, as a pretty thing, but merely as an article of sale, that will bear a certain profit to the importing merchant and retailing storekeeper, whose knowledge need not extend beyond the buying and the selling of the article in question.

Shew this to a chemist, and he will see at once that according to the modern system of manufactures, to produce this sample, there is required

1st, The knowledge necessary to erect a steam engine, with all the acquirements previously necessary.

2dly, The mechanical knowledge necessary to erect and put in order the complicated machinery for carding, roving, spinning, and twisting cotton.

3dly, The knowledge necessary to the weaving of it into cloth, which under the patent of the Rev. Mr. Cartwright is in England now performed by the power of water or of steam; and in the course of a twelve month will be so performed in this country. I hear it has been done in Boston, and I saw it done with additional improvements by Mr. Siddal's loom about six miles from Philadelphia on the York road.

4thly, The chemical knowledge necessary to bleach the goods to a marketable whiteness. Including the knowledge of alkalies, the method of making and employing oil of vitriol, to which lead works and glass works are necessary: and the method of making and employing, the oxymuriatic acid and its alkaline and earthy combinations.

5thly, The knowledge necessary to the machinery of a print shop and its attendant branches: as

a. The pattern drawer, to whom is paid from a guinea to a guinea and a half a week, and whose sole employment is the inventing and the drawing of patterns on paper. This introduces the trade of colour-making; itself implying no slight degree of chemical knowledge and experience.

b. The block cutter; and finisher who fixes the hat or felting on the block when cut.

c. The fabricator of copper plates, and of turned copper rollers.

d. The engraver of copper-plate patterns.

e. The weaver of the cloths for the printing table; and the roller-work.

f. The knowledge necessary under what circumstances to use the adhesive mixtures of the printer; when to employ, gum arabic, gum senegal, or gum tragacanth; when to employ raw or parched flour; when to substitute gypsum, &c. implying considerable chemical knowledge.

g. The colour man, who mixes the colours and makes the mordants, whose business cannot be well or economically conducted, without considerable chemical knowledge. It is his business to know how to make each mordant proper to fix the colour of each colouring drug; in what proportion the mordant and the drug must be used to give the required colour, when the piece comes out of the dye-copper. What drugs from various quarters of the world, yield not only the required colour, but at the cheapest rate and of the required tinge. In what order and succession the colours are to be printed on the cloth. What patterns will bear colours printed on at once without dying, and what requires to be dyed after printing. How many colours can be raised by one and the same immersion in the dye copper. What colours and patterns require to be printed, dyed, penciled or discharged, to produce the work required in the market. All this and much more is necessary to be known in the colour shop of the printing establishment.

h. When to this we add the knowledge requisite to erect and manage in the best manner, the water works, dash wheels, stoves, calenders, presses, &c. of such an establishment, there can hardly remain a doubt but much knowledge must exist where these establishments are common, more than where they are unknown. But it is not the knowledge required or displayed in each particu-

lar work, that is of so much importance, as that the means of knowledge, and the theory of all these processes, must be of easy access, and generally diffused throughout the country, where it is in constant demand.

This is only one, and of one branch among the almost innumerable manufactures of Great Britain a d the other European nations. Is it possible to doubt, but what they must have more knowledge upon the whole than we have, whose concerns need it not? Is it not evident that there is and must be among these people, more general energy in the various classes of society, and more accumulation of real power than among us? For knowledge is power. All these objects of exertion by means of which Great Britain lays the world tributary at her feet, furnish her with wealth—and furnish her with men too in time of need: men for defence, and men for offence. It is manufacturing machinery that furnishes men who can be spared when they are wanted—it is manufacture that cloaths, ay and manufacture that feeds them: for the general energy, and aim at improvement in manufactures, extends to and influences every other branch of industry: hence the English are the best *farmers* in Europe, precisely because they are the best *manufacturers* in Europe.

And yet some years ago, in the Legislature of the United States, it was gravely asserted, debated, and voted, by men who were the advocates of our dependence on Great Britain for the manufactured necessaries of life, that we were the most enlightened nation on the face of the earth! and this circumstance too, this vote, was one of the proofs of the assertion! and the silly declaimers who advanced this modest position, deemed themselves no doubt among the wisest of the wise! In manufacturing speeches—in debating for days what might be decided in minutes, we do excel.

I do sincerely wish that the people would once begin to imagine, that legislators who talk the longest are not therefore the wisest; and that there may be some truth in the old proverb, that empty vessels sound the most. In our debates it must be confessed that if our knowledge be not very profound, it is in our own language, very lengthy. In natural talent, in force of body and vigour of mind, we are inferior to no nation that I am acquainted with: but I think that even while I am writing (September 1814) proof is afforded, that we should be greatly improved by European cultivation and European discipline; for these have made beings our superiors, who in every natural endowment of mind and body are scarcely our equals.

In the outline I have given of Werner's theory of the earth with a few additional ideas of my own, it must be obvious, that it does not account for metallic strata or veins of late formations. Nor will the Neptunian hypothesis of watery crystallization answer the purpose as I think: nor can I adopt the Plutonian theory of Hutton and Playfair, who suppose the veins of metallic substance to have been filled by injection from below. To me it seems that we want light on the subject, and must await till more facts be recorded and compared. T. C.

IRON.

Preliminary Essay upon the theory of Assaying as applied to the ores of IRON.

In the wide and important range of chemical investigation, few subjects present themselves to our notice which have so extensive a relation to the wants and comforts of life as the various manufactures of iron. First on the list of necessity, and yielding to none

as a material of luxurious refinement, this real king of metals, governs, assists, or modifies every operation which stimulates the ingenuity of man. Every trade without exception is dependent on it, while it borrows the aid of but very few in return. Agriculture and mechanics, chemistry and mineralogy, astronomy and navigation, all confess its universal utility. Medicine respects it—surgery might almost worship it. Painting is indebted to it for many of her favourite colours, and music for some of her sweetest sounds. Universally diffused throughout our globe, we trace it under every form, assuming every hue, mingling in every combination—the favourite instrument of the wisdom and goodness of the Deity. It enters into the composition of all our food—it constitutes an important portion of the soil which supports us. It sparkles in the eye of health, and blooms in the blushing cheek of youth and beauty—it tints the gems of the mine and the flowers of the forest, and its powerful influence presides in some measure over every production of art, and every process of nature.

When we reflect on the unlimited usefulness, the inexhaustible variety, and the interesting difficulties which this substance displays to our consideration, it may seem matter of surprise that it should not have been already thoroughly examined by scientific men; and indeed the author of this sketch was long of opinion that nothing remained for investigation. The better he became acquainted with the subject however, the more fully was he convinced, that from some cause or other, iron has not obtained a due share of attention; that disputes about absolute caloric, or the radical of muriatic acid, or the constituents of the precious stones, or the exact specific gravity of the gasses, with an hundred other chemical investigations, which, even when discovered, add but little to our knowledge and nothing to our happiness—have puzzled the judgement and distracted the invention of philosophers, while the humbler, more attainable, but incomparably more important processes of manufacture, lay neglected or forgotten. Thus in the essays of the celebrated Klaproth, which are models of science and consummate skill, there is not a single analysis of the ores, or oxyds of iron; and Boucher and Courtivreau, the French academicians, though the authors and compilers of a long and elaborate treatise on the arts of the furnace and the forge, gives us no reason whatever for supposing that they ever made an experiment upon the subject. Swedenborg has also furnished a minute and verbose account of the Swedish modes of manufacture, which is equally destitute of chemical investigation; abounding however, like his

famous system of theology, in fanciful assertion and hypothetical conjecture. Rinman has written largely and originally upon iron, but his observations as well as those of Reaumur, are principally directed to its changes into steel. Cramer's metallurgy, gives us an indifferent process for reduction in the small way, and Gellert has described a very excellent mode of effecting the same operation. Bergman, Vauquelin, Proust, Thenard, Lussac, Clouet, Guineveau, Hatchett, Berthollet, Morveau, Duhamel, and very many other and able chemists have undoubtedly done much to investigate the properties of iron, but in general their investigations overlook the primary processes of manufacture, and although they read well in a system of chemistry, afford but few rules that are applicable to practice. The iron master has yet to learn some tolerably simple and certain mode of assaying his ores, and forming a previous judgment of the quality of his iron, and continues for want of such knowledge, to be exposed to immense loss, and sometimes to irretrievable ruin.

The only author that I have read, who appears to entertain correct ideas upon this subject, is Mr. Mushet of Scotland, and assuredly his experiments bear a closer relation to practical utility than any others that I have seen. But whether it be that the kinds of ore which he principally treats on, vary in their composition from those of the same species and subspecies which we use in this country, or whether the nature of his crucibles or the power of his assay furnace, differ very widely from those which I have employed, certain it is, that in endeavouring to repeat his experiments, I have frequently obtained very different results; and have been forced notwithstanding the high respect I have long entertained for his authority, to believe him in some important respects, entirely mistaken. In the present paper I shall notice some few of his observations which I consider erroneous, and which from the publicity bestowed on them in your highly useful and excellent work, have obtained general circulation.

As the remarks and researches which I have made on this subject are intended to refer immediately to practice, I shall begin with the first operation which the ore generally undergoes, viz. torrefaction or *roasting*.

"The consequence of heating ironstone exposed to the air," says Mr. Mushet "is a loss of water, sulphur and carbonic acid." In proportion as these are carried off, the metal becomes more and more revived, and of course more liable to attract and fix

oxygen, thus becoming more difficult to be reduced than ever. This is indicated by its swelling in bulk and losing its magnetic virtue. Upon this supposed absorption of oxygen, unsupported as it is by any experiment that I know of, Mr. Mushet's whole theory of torrefaction is erected.

Now with respect to the fact that ironstone over roasted, loses its magnetic property, it is true only as it regards the presence of sulphur. I have repeatedly torrefied the fine argillaceous ironstone of Bassenheim iron-works, from a low red to a fusing heat, and found its magnetism in the last stages increase instead of diminishing. The result was very different however, when the ore contained sulphur. It then fused much sooner, became porous, and spongy, and lost its magnetism altogether. If it were oxygen that produced the effect in the one, it ought also to have produced it in the other. The obvious inference must be, that Mr. Mushet erected his theory upon the examination of sulphureous ironstone, without observing the difference; since indeed he not only neglects taking into consideration the effects of sulphur generally, but even ridicules the folly of those manufacturers who consider its agency of such importance.

But there is another powerful reason against this supposed increase of oxygen, derived from the very principles of the ore itself. For ironstone can in most cases be considered in no other light than a peroxyde of iron; already subjected as it most probably has been, to oxydation, during centuries,—it must long since have reached its point of saturation, and therefore might part with, but assuredly cannot acquire oxygen during the operation of roasting.

To ascertain this matter however beyond all dispute I took some of this sulphureous ironstone which had been torrefied till it fused into a light cellular mass of a dark livid blue colour, totally destitute of magnetism. This I pulverized, and having again satisfied myself that not an atom of it was attracted by the magnet, I put it into a glass with some sulphuric acid. An immediate action was perceived and a smell of hydrogen emitted. I diluted the acid and let it stand for a couple of hours, when on testing it by prussiat of lime, a greenish blue precipitate instantly apppeared. It is hardly necessary to mention to the chemical reader, that the prussiat of lime here employed, is preferable to the prussiat of potass as a test, unless this last be very carefully prepared, because the prussiat of potass as commonly used is apt to be decomposed where there is an excess of acid, but the prussiat of lime (unless

much heated) is never liable to this fallacy. The object of this experiment is obvious. It is well known that a solution of sulphat of iron (and indeed of all the salts of iron) deposits its base after standing some time, because the iron becomes too much oxyded to remain in solution, and yet after this spontaneous precipitation had taken place, the iron is only what is called an ochre, is perfectly magnetic after slight roasting, and is the same in effect as the bog ores in the greater part of all countries which abound in pyritous stone coal. (Vide Henckel's Pyritologia). Therefore it is evident that the ore in this experiment did not contain a full dose of oxygen, or else it would have been insoluble, still less could it contain a quantity of it destructive to its products in the blast furnace, since it actually contained less than the class of bog ores, which are acknowledged to be among the easiest worked, of all the ores of iron.

It is to be lamented that a man of such perseverance, experience and skill in the manipulations of the assay furnace, should have entertained so strong an impression of the injurious tendency of oxygen, and overlooked so obvious and powerful a mineralizer as sulphur is known to be. Perhaps the reason was that he conceived no notable portion of sulphur could exist in combination with the one unless it appeared plainly in the roasting, for he says expressly that if the pulverized ironstone be thrown into a red hot vessel, the presence of sulphur (if any!) will instantly be manifested by a dark lambent flame and a suffocating vapour. Now I can assert, upon my own experience, that an ironstone which contains so much sulphur as to produce but little and extremely bad iron in the furnace and in the assay crucible, may notwithstanding be thrown to the quantity of four ounces upon a red hot iron plate without exhibiting any flame or emitting any perceptibly sulphureous odour. That consequently, this mode of discovering sulphur cannot in my opinion be at all relied on. Certain it is indeed, that where these appearances are present, the ore must be exceedingly sulphureous, but it is equally certain that ironstone may be contaminated with sulphur to a very mischievous excess, without shewing any such appearances whatever when tried in the mode which he recommends; although when a very large quantity is burnt in a pile and for several days together as at furnaces, the sulphureous acid gas can be readily perceived even at several yards distance. The cause of this odour, cannot be mistaken where wood and charcoal are used for the purpose of torre-

faction, as is generally the case in the United States; but where stone coal is employed, for that purpose, as it is in Scotland, it might very readily escape notice.

I shall pass by some of Mr. Mushet's intermediate observations upon this subject, and proceed at once to his conclusion, which I conceive would in many cases produce very injurious effects if reduced to practice. "I look upon it" says he "to be a desideratum in the preparation of ironstone, to contrive a mode which would either deoxygenate the ore unexposed to external air, with a degree of certainty which would preclude the possibility of the ore's attracting more oxygen." The meaning of which appears to be, to exclude as much as possible the action of the atmosphere.

Before I make any further remarks upon Mr. Mushet's theory, I shall lay down what I consider the objects and rationale of the roasting of ores of iron previous to their entrance into the furnace. To do this the more readily I shall divide them into two classes. 1st. Comprehending those ores which do not contain any perceptible portion of sulphur or arsenic. 2dly. Those ores which are considerably mineralized by one or both.

Now, when ores of the first class are too large to be put into the furnace without breaking, and too hard to be broken without the assistance of heat—they are roasted; and although every manufacturer may not know the reason of the operation, it is simply this, that they may be broken in smaller pieces and with less labour. The proof of this is, that all the bog ores without exception are used raw, although they contain fully as much carbonic acid, water and oxygen as any ore whatever. Moreover when mountain ore occurs small enough to do without breaking, as is sometimes the case, the operation of roasting is omitted also. I have seen instances of this last at Warwick and Joanna furnaces of this state, where they used their ore without any preparation, and have myself in a case of emergency, had a considerable quantity of raw ironstone put into the furnace without any bad consequences resulting from it. Consequently we may safely assume it as a decided fact that the presence of water and carbonic acid in the ore has no injurious effect upon the operation of smelting.

Let us on the other hand consider torrefaction as applied to an ironstone containing a quantity of sulphur. Here we shall have to operate upon a substance, known to possess a strong attraction to iron in all proportions from 1 to 55 per cent. and in all these

possessing a bad effect upon the quality of the metal. The effect of the roasting ought now to be, not only to render the ore easily broken as before, but also to expel the greater part of the sulphur, in some measure by sublimation and chiefly by acidification. In this process the sulphur combines with oxygen sufficient to convert it into sulphureous acid, which is extremely volatile and which does not act upon iron, and this flies off in vapour producing the peculiar smell that proceeds from sulphur when undergoing combination. In this way the sulphur may in most cases be burnt off, but cannot be got rid of by sublimation alone; because for this purpose it would be necessary that the air should be totally excluded and at the same time that a free passage should be afforded to the sulphureous vapour—a combination absolutely impossible without a radical change in the whole of the present system of torrefaction.

Upon this subject, which is indeed as Mr. Mushet considers it, fully entitled to the utmost attention of the manufacturer, I shall bring to my support the experiments of M. Guineveau upon desulphuration, by which it is plainly shewn that a free concourse of air is necessary to the process; and that it can neither be performed in close vessels by the most carefully conducted distillation, nor in a covered crucible by the strongest fire. The Swedish iron masters' mode of torrefaction as detailed by Swedenborg is decidedly in favour of the same opinion. Their ores are always roasted with dry wood, and he mentions some instances in which he has heard of the process being repeated three times in order to expel the sulphur. Their success must be good, since they make the best iron in Europe, yet they never exclude the atmosphere; on the contrary their mode of operation ensures a steady and great supply of this important agent, and the author I quote from, particularly states that the suffocating odour of burning sulphur (that is to say of sulphureous acid gas) is always very perceptible and that for several days together from the same pile. Nay even the British mode with which Mr. Mushet finds so much fault, is in that respect tolerably advantageous, since I should think the swelled and spongy form which the coal assumes in coaking, must be very favourable to keeping up a supply of air for a considerable time and thus tend greatly to remove the real enemy of the smelting process—not oxygen, but sulphur.

If these principles be correct, and they have received the stamp of practice as well as the seal of scientific investigation, it

follows, that were we to roast a sulphureous ironstone without admitting the air as Mr. Mushet advises, we should not get rid of the sulphur at all, that small portion excepted which might be able to make its way through his nearly impenetrable covering of pit coal coak dust, and thus instead of improving upon the process in common use, we should really substitute one incomparably worse: a mode indeed, where the ore is very sulphureous, which would alone be fully sufficient to frustrate every future operation—to ruin the undertakers and cast disgrace upon the undertaking.

To sum up the whole of what has been stated, I should comprise it in the following rules, viz:

That when the ore contains neither sulphur nor arsenic it *cannot* contain any other principle which requires the process of torrefaction for its expulsion. Therefore, *That* when the ore is not mineralized and does not require pounding, roasting is unnecessary. *That* when it is not mineralized and *does* require to be pounded, it is no matter for that purpose how the heat is applied, whether with air or without it. *That* when the ore is mineralized, whether it needs pounding or not, it must be torrefied,—and *that* in this latter case, air is not only *not* prejudicial but absolutely necessary for the purpose.

There is yet one part of this subject which demands notice and that is the degree to which the heat should be raised in the process of torrefaction. The importance of this circumstance also depends in a great measure upon sulphur. When this injurious substance is present, the heat should be long continued, and must *not* be so great as to fuse the ore. When the ore contains no sulphur, it is no longer of so much consequence, except that it is a waste of combustibles in the pile and of some small quantity of coal in the furnace. The reasons for this opinion are I conceive as follows.

It is generally found, at least throughout the argillaceous species of ores, that sulphur is *chemically* combined with a small portion of the iron, in the state of pyrites, but only mechanically combined with the great body of the ironstone. Now the united effect of heat and air, is to expel this sulphur in the form of sulphureous acid gas, so long as the ore is not heated to the fusing point. But as soon as this is the case, the surface becoming glazed, denies a passage inwards to the air, and outwards to the sulphureous vapour, and the chemical combination which before existed only in a small part, becomes extended through the whole mass,

thus changing the metallic portion of the ore into a sub-sulphuret of iron. The ore in this state is conveyed to the furnace and thrown into a situation where scarcely a particle of free oxygen can be conveyed to it, until it has descended nearly its whole distance, and where of course it has but little chance of losing any portion of its sulphur except what the hydrogen of the charcoal may dissolve and dissipate. The greater part therefore, unavoidably remains in combination to the last, changing nearly the whole into cinder and debasing to the most worthless degree the small portion of iron which can under such circumstances be produced from it. In the assay crucible I have found the effect exactly similar, when the flux used was properly adapted to support the analogy between the small and the large way of operating. The effect of Mr. Mushet's proportions of flux, and the reasons why those proportions have probably led to such erroneous inferences will come more methodically before us in a future paper.

The injurious effects of too great a degree of heat on an ironstone which does not contain sulphur, are simply that it wastes fuel unnecessarily—that the ore is afterwards less easy to pound than if properly roasted—and lastly, that the increased density and hardness of the mass makes it probably more difficult for the vapour of cementation to pervade, and this contraction I have generally attributed to the large proportion of clay with which these ores are always united.

Thus it is best in all cases that the ore should not be fused. But with a sulphureous ore this circumstance is of the greatest importance. Sulphur, and nothing else will account for the difference, nor can I perceive that oxygen has any thing to do with it.

The relation which the magnetic property bears to the value and richness of iron ores, and the reasons why torrefaction exhibits this property in so remarkable a degree, will form the subject of my next communication. J. H. H.

Remarks by the Editor.

The preceding paper is well worth attention on a very important part of the process of smelting iron ores.

The ores of iron, appear as ores and not as pure iron, in consequence of the iron contained in them being combined, with sulphur or arsenic or both—or with oxygen in various proportions or

with carbonic acid. The salts of iron, are not used as ores. The combination of iron with phosphorus or its acid, I consider as too uncertain to be noticed. To reduce these ores to iron, the sulphur or arsenic, the oxygen, the carbonic acid, must be driven off. This is done by means of heat and charcoal, whether of wood as in this country, or of fossil coals in England.

When ores are roasted previous to smelting, with a heat not exceeding a red heat, they are

1st. Rendered more friable: more easily broken.

2d. Sulphur and arsenic if combined in them, are driven off, partly in the form of sulphur and white arsenic, and toward the close of the operation the sulphur is acidified by the air, and flies off in the form of a suffocating sulphureous acid gas.

3d. By heat also, the carbonic acid gas is partly driven off during roasting. Hence by roasting with coal dust, a part of the operations of the smelting furnace are forestalled by means of a cheap fuel: and where the ores contain sulphur this is more effectually driven off by roasting in the open air, than it could be in the furnace, where its escape would be perpetually intercepted by the great body of ore, fuel, and flux.

I believe it to be true, that the last portions of sulphur must be driven off by being acidified in contact with atmospheric air: but where the ore is, as it generally is, merely an oxyd, or an oxydule, I have no doubt but the oxygen is encreased instead of being diminished, by roasting, unless plenty of charcoal dust be used; which by yielding carbon, converts the oxygen of the ore into carbonic acid. That iron in a red heat will *greedily* imbibe oxygen from the atmosphere, no one who has seen finery cinder, or the scales of a common blacksmith's shop, can doubt (I think) for a moment. Nor can the iron be oxygenated to the utmost, without ignition, as any one may see by exposing yellow ochre to heat till it becomes red ochre, which is a peroxyd.

Hence, where the iron is sulphurated, my correspondent's remarks apply fully, and they are important. Where the ore is a mere oxyd, not perfectly saturated with oxygen, as the case generally is, I think the roasting with plenty of charcoal dust, and stopping the operation rather before the charcoal dust is consumed, is the proper method to be adopted; for if the oxygen of the ore be in great measure driven off by roasting, it will certainly be restored, if the ore be exposed to the action of the air in a red heat after the charcoal is consumed.

So far as I know, the magnetic qualities of iron or iron ore, have little or no practical effect in the operation of smelting. We know too little as yet about magnetism, to draw practical inferences.

It seems to me of no consequence whether the argillaceous part of the common iron ore be hardened or not by roasting. The earth must be converted into glass in the furnace, or the iron will not be obtained. The action of the lime on the clay is the same, whether this latter be hard or soft. Let it be remembered, that in a very great degree the art of pottery, the art of glass making, and the art of smelting depends on this fact, viz.

Put into a crucible a round lump of pure clay: into another, a similar lump of pure lime or even limestone: into another a similar lump of pure flint, silex, or quartz. Expose them for any length of time to a violent heat, they will continue as at first, clay, lime, and flint, except where the sides are in contact with the crucible. Pound them together, and put them in one crucible; expose them to heat for the same time, and the product will be perfect glass. As potass will dissolve silex, it may be substituted for lime.

T. C.

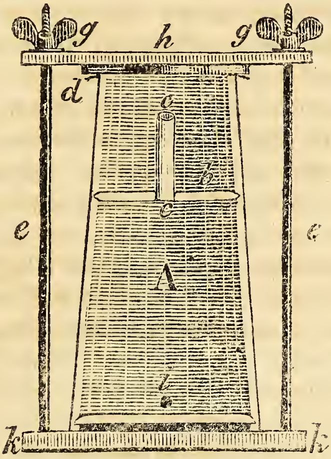
SELTZER WATER.

PHILADELPHIA, Feb. 1814.

Dear Sir—In a note to your edition of Accum's Chemistry, I find that you mention a contrivance of Mr. Cloud for preparing what is commonly called mineral, but more properly aerated water, or for saturating water with carbonic acid gas. It may not be improper to notice, for the information of your readers, that although the plan would appear very economical, and answer the purpose completely, yet the truth is, that with an apparatus made according to Mr. Cloud's direction, (in a superior style, which cost $ 40) the saturation was difficult to effect to that degree equal to the machine with the forcing pump. Mr. C. from his own, as well as from the evidence of Messrs. Patterson and Eckfeldt of the U. States' mint, prepared aerated water with his apparatus; but with the one made by Mr. Glentworth and myself, no *saturation* other than an impregnation could be effected. We followed

the directions of Mr. Cloud in every particular, and in order to secure success, we procured two powerful screws, and an iron head; the latter was adapted the moment the vessel containing the chalk and diluted sulphuric acid was put in.

Description of the apparatus.—In order to understand the plan more fully, we subjoin the following figure, which may, probably, lead to some improvement, which would obviate our objections:



The vessel we had made, was of strong oak, with staves of 1½ inches in thickness, of the figure of a churn, as A and contained about 18 gallons. At *b*, is a partition made in the vessel, at the time it was formed. At *c*, is a hole of about two inches diameter with a wooden pipe *c*, to screw it in or out at pleasure. At *d*, there is a circular iron head made to fit on the top of the vessel A, under which is placed thick paper before the head is screwed on by the screws *g*. *g* At *h*, is a wooden piece made of thick plank perforated at the ends, so as to admit the iron bars *e*. *e*. which are fastened to a plank at bottom *k*. *k*. At *i*. is an aperture for a stop-cock to let out the water. The distance from *b*. to the top, is about one-third of the length of the cask.

The Operation. The vessel A, is filled with river water to within an inch of *b*. The pipe *c*. is then screwed in: a vessel of stone-ware holding about two quarts, is then provided, in which is put one pound of chalk in small lumps, and a diluted mixture of sulphuric acid in the proportion of 6 ounces to one pint of water.

The vessel thus prepared, is set on *b*, in the vessel, and the top is screwed on immediately. In the course of three hours, the water in the vessel may be let off. The saturation or impregnation will be found to equal the water made in Nooth's machine. But Mr. Cloud says, that the strength of water made in his apparatus was equal to that prepared by the assistance of the forcing pump, which is a costly and an expensive mode. I intend to have a pipe to run from *c*. to the bottom of the vessel, so that the gas may pass *through* the water, in its ascent from the bottom. It is plain that the pressure is given, by confining the gas in a small compass, and the necessity it is under of combining with the water, or of breaking the apparatus. To avoid the latter, the vessel should be strong and well made. On ours, we had 15 iron hoops. I hope, that, on further trial, the apparatus may be found to supersede the complicated one with the forcing pump, and the glass one of Mr. Nooth.

As to the aerated waters generally, I am of opinion, that every family should have an apparatus of the kind, in order to make them at any time; for the purpose of medicine, and salutary beverage. I found them in a recent complaint of more service than any other preparation. Owing to extreme debility, no medicine or food would stay on my stomach until I drank the seltzer and soda waters; and I am of opinion, that by their use, sickness may be avoided, and of course health preserved.

I am sir, your's, &c. JAS. CUTBUSH.

T. Cooper, Esq.

Remarks by the Editor.

Mr. Cloud's and professor Patterson's machine for making seltzer water, I saw in operation at the mint. The water was strongly impregnated with carbonic acid, and sufficiently so. I had one made on the same plan a few months afterward; but I could never succeed in making the water sufficiently aerated. I shewed mine to an intelligent man of this city, Mr. Jones, who wished to make the seltzer and soda waters for sale. He had one made lately with every precaution, but his too did not succeed. Certainly the principle and the plan of Mr. Cloud's machine are very simple and in theory sufficiently efficacious, but I am at a loss to discover what our want of success is to be ascribed to, unless it be to defect in workmanship. T. C.

COLOURED FLAMES.

The colours of the flame produced by burning cotton dipt in some of the neutral salts in spirit of wine.

Neutral	*Salts.*	*Colours of their flames.*
Muriates of	Soda	Bright yellow.
	Ammonia	Brownish yellow.
	Lime	Red yellow (Deep.)
	Magnesia	Red yellow.
	Barytes	Pale yellow.
	Strontian	Deep red.
	Allum	Reddish.
	Iron	Sparkling yellow.
	Manganese	Sparkling red-yellow.
	Tin	Pale bluish.
	Copper	Green with yellow.
	Iron and Strontian	Sparkling reddish.
Acetites of	Iron	Reddish yellow.
	Lead	Bright red yellow.
	Alumine	Beautiful purple yellow.
Nitrates of	Potash	Beautiful purple.
	Soda	Beautiful reddish yellow.
	Lime	Beautiful reddish yellow.
	Lead	Red yellow.
	Bismuth	Red yellow.
	Silver	Reddish yellow.
Sulphats of	Iron	Reddish yellow.
	Copper	Green.
	Zinc	Reddish yellow.
	Magnesia	Reddish yellow.
Nitro-Muriat of Platina		Yellow.
Chromat of Potash		Purplish red.
Prussiat of Potash		Reddish yellow.

JOHN TYLER LINTON,

Dickinson College.

Mr. Hord, of Virginia, one of my chemical students at Dickinson College, has lately taken out a patent for facilitating the crystallization of salt, by the application of a vacuum. About one-third of the fuel is saved, as is said.

T. C.

WEAVING.

The Rev. Edward Cartwright. Weaving by Machinery: Patents. Poetry.

I have already introduced this Gentleman to my readers, as the inventor of a new method of giving rotatory motion in a steam engine—as the inventor of a new method of keeping the piston in close contact with the internal surface of the working cylinder—as the inventor of a new method of condensing steam by a large surface of thin metallic plates, exposed to the action of cold water within and without; an invention that will continue to be applied as I think, in all future improvements on the steam engine.

I have introduced him to my readers as the inventor of weaving by water-power or by steam. Some time about the year 1791, his first experiment (near Castlefield in Manchester) of weaving by means of steam succeeded so well, that it was set on fire after having continued in operation about two months. A few years ago, the parliament of England, granted him a further term for his patent, but I have not heard whether the principle is yet brought into extensive operation. It is with difficulty and management that machinery can now be introduced into that kingdom, if it suddenly interferes with the employment of the poor. The risings of the populace against the new invented stocking loom, a year or two ago, is a proof of this. These stocking looms I hear are now manufactured in New York; information of which I request my readers to take notice.

Looms for weaving *plain* goods without the aid of a professed weaver, by the power of horses, of water, or of steam, are now in full use near Boston. Some time ago, I saw at Harrisburgh a loom of this kind, in which the shuttle was thrown and the treadles worked by a very simple motion that might be given by the hand or by any kind of machinery that could communicate an impulse to and fro. I understood that a Mr. Janes had obtained a patent for this invention. I can bear testimony that looms were driven by steam power about the year 1791 in Manchester. It seems to me a kind of speculation in the Eastern states, to look over the Repertory of arts, and to take out patents for English inventions, and sell the patent rights to the more careless and credulous manufacturers in the Southern states. But I wish it were recollected, that by the laws of the United States, no patent can be legally

obtained for an invention already invented: no man can legally obtain a patent under our federal laws, for merely introducing a process or machine invented elsewhere.*

To the best of my recollection, neither in Mr. Cartwright's or in Mr. Janes's loom was there any contrivance that the work should stop when a thread broke. While the thread continued whole in the shuttle, the work was good; but when it broke, and a boy was not at hand to stop the motion, the work went on indeed, but was defective. This defect I saw obviated by a very ingenious contrivance in a loom constructed by Mr. Siddal, and at work about 5 or 6 miles from Philadelphia, at the Calico printing works, near the old York Road. For this invention I believe Mr. Siddal has obtained a patent, and the inventor of it certainly deserves one.

The most profitable (that is permanently profitable) manufacture any person can enter into in this country at the present time, is an establishment that should combine the carding, the spinning of cotton—the weaving by looms similar to those mentioned above, of plain calicoes, shirtings, sheetings and table cloths—the new

* Extract of a letter from a friend. "You may have noted that the patent board, while it existed, had proposed to reduce their decisions to a system of rules as fast as the cases presented should furnish materials. They had done but little when the business was turned over to the courts of justice, on whom the same duty has now devolved. A rule has occurred to me which I think would reach many of our cases, and go far towards securing the citizen against the vexation of frivolous patents. It is to consider the invention of any new mechanical power, or of any new combination of the mechanical powers already known, as entitled to an exclusive grant; but that the purchaser of the right to use the invention, should be free to apply it to every purpose of which it is susceptible. For instance, the combination of machinery for threshing wheat should be applicable to the threshing of rye, oats, beans, &c. the spinning machine to every thing of which it may be found capable: the chain of Buckets, of which we have been possessed thousands of years, we should be free to use for raising water, ore, grains, meals, or any thing else we can make it raise. These rights appear sufficiently distinct, and the distinction sound enough to be adopted by the judges, to whom it could not be better suggested than through the medium of the Emporium, should any future paper of that work, furnish place for the hint."

I have no doubt whatever of the justice of these ideas, or of the propriety of adopting them. T. C.

invented stocking loom—and printing in single colours engraved patterns by roller work. Such an establishment should peace come to-morrow, under protecting duties of 25 per cent. must succeed so as to satisfy any reasonable wishes. Remember, at present *cotton* is our staple: the day is fast approaching when we shall even become exporters of *wool* as a raw material. The people of this country are not aware, that we shall never conquer England but by means of our manufactures. To this mode of warfare, they are driving us with all their might; and it is not too much to apply to them, Quem Deus vult perdere, prius dementat.

By the inventions above mentioned, the greatest of all our difficulties in the manufacture of cotton goods, viz. the scarcity of weavers, is now obviated; and I hope the information here given will spread and be made use of.

Having introduced the Rev. Mr. Cartwright (not major Cartwright the Duke of Richmond's correspondent—the persevering advocate of a parliamentary reform, who will never live to see the persons in power reform their own abuses) as an inventor of steam engines and of looms worked by machinery, I now introduce the same Gentleman, as a physician and a poet, the last character being the earliest in which he received the well-merited reward of public approbation.

His proposal of curing typhus and typhoid disorders, by *yeast*, as the vehicle of wine and bark, deserves more trial than it has received. Dr. Percival and Mr. Henry of Manchester used it frequently, and commended it highly: they used yeast also as an application to ill conditioned ulcers, with good success; though I suspect, that of local applications of this nature, Mr. Walker's carrot poultice is one of the most efficacious. I am persuaded however that much may be done in those disorders also by oxygen, by nitrous oxyd, and by oxymuriat of potash and soda. The gasses have not yet had fair play as medicines: the failure of Dr. Beddoes and Mr. Watt in Pthisis, produced something like a prejudice against them: though the cases of Dr. Thornton surely deserve repetition.

I insert the poem of Armine and Elvira, because I do not recollect that it has been published in this country: because at any rate, it is little known: because it contains some images so beautiful, as hardly to be excelled in the whole range of descrip-

tive poetry: and because the elegant acquirements of a gentleman so eminent for mechanical improvements, well deserve to be generally known.

T. C.

*On the efficacy of Yeast in the cure of those diseases known by the name of Putrid.**

A remedy, which contains much fixed air, has been lately started by the Rev. Mr. Cartwright, which merits the highest attention. Seventeen years ago, says this gentleman, I went to reside at Brampton, a very populous village near Chesterfield. I had not been there many months before a putrid fever broke out among us: finding by far the greater number of my new parishoners much too poor to afford themselves medical assistance, I undertook, by the help of such books on the subject of medicine as were in my possession, to prescribe for them. I early attended a boy about fourteen years of age who was attacked by this fever; he had not been ill many days before the symptoms were unequivocally putrid. I then administered bark, wine, and such other remedies as my book directed. My exertions, however, were of no avail; his disorder grew every day more untractable and malignant, so that I was in hourly expectation of his dissolution. Being under the absolute necessity of taking a journey,—before I set off I went to see him, as I thought, for the last time, and I prepared his parents for the event of his death, which I considered as inevitable, and reconciled them in the best manner I could to a loss which I knew they would feel severely. While I was in conversation on this distressing subject with his mother, I observed in a corner of the room a small tub of wort working; the sight brought to my recollection an experiment I had somewhere met with, of a piece of putrid meat being made sweet by being suspended over a tub of wort in the act of fermentation. The idea instantly flashed into my mind that the yeast might correct the putrid nature of this disease, and I instantly gave him two large spoonfulls. I then told the mother, if she found her son better, to repeat this dose every three hours. I then set out on my journey:

* The contents of this article cannot be too generally known. How many valuable lives are yearly lost by putrid sore throats, fevers, &c. which might be saved to the community, and to their relatives, if the cure here recommended were generally known and resorted to! with proper medical aid, however, where it can be had. Arthur Young.

upon my return, after a few days, I anxiously inquired about h e boy, and was informed he was recovered. I could not repress my curiosity: though I was greatly fatigued with my journey, and night was come on, I went directly to where he lived, which was three miles off, in a wild part of the moors; the boy himself opened the door, looked surprisingly well, and told me he felt better from the instant he took the yeast.

After I left Brampton I lived in Leicestershire: my parishioners being few and opulent, I dropped my medical character entirely, and would not even prescribe for any of my own family. One of my domestics falling ill, accordingly the apothecary was sent for; his complaint was a violent fever, which in its progress became putrid: having great reliance, and deservedly, on the apothecary's penetration and judgment, the man was left solely to his management.

His disorder, however, kept daily gaining ground, till at length the apothecary considered him in very great danger: at last, finding every effort to be of service to him baffled, he told me he considered it as a lost case, and that, in his opinion, the man could not survive four-and-twenty hours. On the apothecary thus giving him up, I determined to try the effects of yeast. I gave him two large table spoonfulls; in fifteen minutes from taking the yeast, his pulse, though still feeble, began to get composed and full. He in thirty-two minutes from his taking the yeast was able to get up from his bed and walk in his room. At the expiration of the second hour I gave him a bason of sago, with a good deal of lemon, wine, and ginger in it; he ate it with an appetite: in another hour I repeated the yeast; an hour afterwards I gave the bark as before; at the next hour he had food; next he had another dose of yeast, and then went to bed; it was nine o'clock. I went to see him the next morning at six o'clock; he told me had had a good night, and was recovered. I, however, repeated the medicine, and he was able to go about his business as usual.

About a year after this, as I was riding past a detached farm-house at the outskirts of the village, I observed a farmer's daughter standing at the door, apparently in great affliction; on inquiring into the cause of her distress, she told me her father was dying. I dismounted, and went into the house to see him.

I found him in the last stage of a putrid fever; his tongue was black, his pulse was scarcely perceptible, and he lay stretched out, like a corpse, in a state of drowsy insensibility. I immediately

procured some yeast, which I diluted with water, and poured it down his throat. I then left him, with little hopes of recovery. I returned to him in about two hours, and found him sensible, and able to converse. I then gave him a dose of bark; he afterwards took, at a proper interval, some refreshment; I staid with him till he repeated the yeast, and then left him, with directions how to proceed. I called upon him the next morning at nine o'clock, and found him apparently well, walking in his garden: he was an old man upwards of seventy.

I have since administered the yeast to above fifty persons labouring under putrid fevers; and, what is singular, continues this benevolent clergyman, "I have not lost one patient."

Dr. Thornton, whose opportunities have been great in putrid fevers, having the superintendance of a dispensary* which includes the poor of nine parishes, and is situated in the vicinity of St. Giles's, has made frequent trials of yeast, and speaks highly in its praise.

One day, says the Rev. Mr. Townsend, by accident, as Dr. Thornton went past a shop† in Tottenham-Court-Road, he heard the screams of a mother who was agonized on seeing her child, as he thought, expire. These screams renewed the struggles of the child, and the nurse who attended threatened to take away at this moment the child, that it might die in quiet. Dr. Thornton got down immediately some tartar emetic, which quickly acted as a vomit; and after the operation was over he gave rhubarb, which cleared the intestines; he then ordered the child, every two hours, yeast and water, with wine and bark, and in three days the dying child was up and well.

The infection had spread to two others in the same house: in this child, and in another, the putrid fever was attended with swelled glands, which suppurated, and threatened gangrene: in a robust servant girl it took the form of a dreadful putrid sore throat; she had an emetic, and afterwards some rhubarb, then yeast and water every two hours. The first effect of this newly discovered remedy was that of rendering the pulse fuller, and fifteen beats less in a minute, and her black tongue soon assumed a clean and red appearance: without bark or wine she was speedily recovered.

In Dr. Beddoes's Considerations there are the following cures: Mr. Caldwell, engraver, (as Dr. Thornton reports,) requested him

* The General Dispensary. † Mr. Burford's.

to go into Green-street, Leicesterfields, to attend Mr. Hadril, who, he said, it was supposed would not outlive the day. I found him labouring under a dreadful putrid sore throat; the tongue was black and thick coated, and the pulse quick and fluttering: evacuations being first premised, yeast and bark in porter were exhibited every two hours. His sister who nursed him, was soon after attacked by the same fever, but the throat was not affected. She was not, like her brother, confined to her bed, but her weakness was so great that she could not walk across the room, nor even stand up half a minute without support. In both these cases the relief from the yeast was very striking, and they were soon cured: the wife was also infected, who received a similar benefit from the yeast.

The most extraordinary cases, however, are the following:—In Husband-street, a small confined situation near Berwick-street, a fever broke out, which, in the short space of a fortnight, in three houses only, swept away six persons. Dr. Thornton's assistance was at this time called in to Mrs. Wollot, No. 1, in that street, who lay delirious and comatose, with her two children, all in the same bed. She refused medicine and food, and was obliged to be drenched, in order to get either down: an emetic and cathartic being premised, they were all put upon the same plan; that is, were to take, every three hours, two-thirds of a glass of fresh porter, with two table spoonfuls of yeast and the juice of half a lemon; and the food, at intervals, was the white of eggs, which Dr. Thornton judged of all things were least subject to putrefy,* beat up with sugar and water; and, as it was the commencement of summer, strawberries were also ordered: and without any further medicine from the apothecary than the emetic and purge, although the woman was at first obliged to be drenched, yet she and her whole family recovered, and this very rapidly.

Among the poor in St. Giles's nothing is administered by Dr. Thornton, after cleansing the primæ viæ, than two table spoonfulls of yeast in some porter every two hours; and out of above forty cases, not one has died under this treatment.

[43 *Young's Annals of Agriculture*—168.

* We know that eggs are kept for a great length of time, and the white, even under the heat of a hen's body, does not putrefy, and it serves as milk to the embryo in the egg.

ARMINE AND ELVIRA,

A

LEGENDARY TALE. BY THE REV. MR. CARTWRIGHT.

IN TWO PARTS.

PART THE FIRST.

A HERMIT on the banks of Trent,
Far from the world's bewildering maze,
To humbler scenes of calm content,
Had fled from brighter, busier days.

If haply from his guarded breast
Should steal the unsuspected sigh,
And memory, an unbidden guest,
With former passion fill'd his eye:

Then pious hope and duty prais'd
The wisdom of th' unerring sway;
And while his eye to heaven he rais'd,
Its silent waters sunk away.

Life's gayer ensigns once he bore—
Ah! what avails the mournful tale?
Suffice it, when the scenes were o'er,
He fled to the sequester'd vale.

"What tho' the joys I lov'd so well,
"The charms," he cry'd, "that youth has known,
"Fly from the Hermit's lonely cell!
"Yet is not Armine still my own?

"Yes, Armine, yes, thou valu'd youth!
"'Midst ev'ry grief thou still art mine;
"Dear pledge of Winifreda's truth,
"And solace of my life's decline!

"Tho' from the world and worldly care
"My wearied mind I mean to free,
"Yet ev'ry hour that Heav'n can spare,
"My Armine, I devote to thee.

" And sure that Heav'n my hopes shall bless,
" And make thee fam'd for virtues fair,
" And happy too, if happiness
" Depends upon a parent's prayer:

" Last hope of life's departing day,
" In whom its future scenes I see!
" No truant thought shall ever stray
" From this lone hermitage and thee.

Thus to his humble fate resign'd,
His breast each anxious care foregoes;
All but the care of Armine's mind,
The dearest task a parent knows!

And well were all his cares repaid;
In Armine's breast each virtue grew,
In full maturity display'd,
To fond affection's anxious view.

Nor yet neglected were the charms,
To polish'd life that grace impart;
Virtue, he knew, but feebly warms,
Till science humanize the heart.

And when he saw the lawless train
Of passions in the youthful breast,
He curb'd them, not with rigid rein,
But strove to soothe them into rest.

" Think not, my son, in this," he cry'd,
" A father's precept shall displease:
" No: be each passion gratify'd,
" That tends to happiness and ease.

" Nor shall the ungrateful task be mine,
" Their native gen'rous warmth to blame,
" That warmth if reason's suffrage join
" To point the object and the aim.

" This suffrage wanting, know, fond boy,
" That ev'ry passion proves a foe:
" Tho' much it deals in promis'd joy,
" It pays, alas! in certain woe.

" Complete ambition's wildest scheme;
" In power's most brilliant robes appear;

" Indulge in fortune's golden dream;
" Then ask thy breast if peace be there.

" No: It shall tell thee, peace retires,
" Of one of her lov'd friends depriv'd;
" Contentment calm subdu'd desires,
" And happiness that's self-deriv'd."

To temper thus the stronger fires
Of youth he strove, for well he knew,
Boundless as thought tho' man's desires,
The real wants of life were few.

And oft revolving in his breast,
Th' insatiate love of wealth and fame,
He, with no common care oppress'd,
To fortune thus would oft exclaim:

" O fortune! at thy crouded shrine,
" What wretched worlds of suppliants bow!
" Forever hail'd thy power divine,
" Forever breath'd the serious vow.

" With tott'ring pace and feeble knee,
" See Age advance in shameless haste,
" The palsy'd hand is stretch'd to thee,
" For wealth he wants the power to taste.

" See, led by Hope, the youthful train!
" Her fairy dreams their hearts have won;
" She points to what they ne'er shall gain,
" Or dearly gain—to be undone.

" Must I too form the votive prayer,
" And wilt thou hear one suppliant more?
" His prayer, O Fortune deign to hear,
" To thee, who never pray'd before.

" O may one dear, one favour'd youth,
" May Armine still thy power disclaim:
" Kneel only at the shrine of truth,
" Count freedom, wealth, and virtue, fame!

Lo! to his utmost wishes blest,
The prayer was heard; and freedom's flame,
And truth, the sunshine of the breast,
Were Armine's wealth, were Armine's fame.

His heart no selfish cares confin'd,
He felt for all who feel distress,
And still benevolent and kind,
He bless'd them, or he wish'd to bless:

For what tho' Fortune's frown deny,
With wealth to bid the sufferer live,
Yet Pity's hand can oft supply
A balm she never knew to give:

Can oft with lenient drops assuage
The wounds no ruder hand can heal,
When grief, despair, distraction, rage;
While death the lips of love shall seal.

Ah! then, his anguish to remove,
Depriv'd of all his heart holds dear,
How sweet the still surviving love
Of friendship's smile, of pity's tear!

This knew the Sire: he oft would cry,
"From these, my son, O ne'er depart;
"These tender charities, that tie
"In mutual league the human heart.

"Be thine those feelings of the mind,
"That wake at honour's, friendship's call;
"Benevolence, that unconfin'd,
"Extends her liberal hand to all.

"By sympathy's untutor'd voice,
"Be taught her social laws to keep;
"Rejoice, if human heart rejoice,
"And weep, if human eye shall weep.

"The heart, that bleeds for others woes,
"Shall feel each selfish sorrow less;
"His breast, who happiness bestows,
"Reflected happiness shall bless.

"Each ruder passion still withstood,
"That breaks o'er virtue's sober line,
"The tender, noble, and the good
"To cherish and indulge, be thine.

"And yet, my Armine, might I name
"One passion as a dangerous guest;

"Well may'st thou wonder when I blame
"The tenderest, noblest, and the best.

"Nature 'tis true, with love design'd
"To sooth the race our fathers ran;
"The savage of the human kind
"By Love was soften'd into man.

"As feels the ore the searching fire,
"Expanding and refining too,
"So fairer glow'd each fair desire,
"Each gentle thought so gentler grew.

"How chang'd, alas! those happier days!
"A train how different now succeeds!
"While sordid avarice betrays,
"Or empty vanity misleads.

"Fled from the heart each nobler guest,
"Each genuine feeling we forego;
"What nature planted in the breast,
"The flowers of love are weeds of woe.

"Hence all the pangs the heart must feel,
"Between contending passions tost,
"Wild jealousy's avenging steel,
"And life and fame and virtue lost!

"Yet falling life, yet fading fame,
"Compar'd to what his heart annoy,
"Who cherishes a hopeless flame,
"Are terms of happiness and joy.

"Ah! then the soft contagion fly!
"And timely shun th' alluring bait!"
The rising blush, the downcast eye,
Proclaim'd—the precept was too late.

PART THE SECOND.

DEEP in the bosom of the wood,
Where art had form'd the moated isle,
An antique castle tow'ring stood,
In Gothic grandeur rose the pile.

Here Raymond, long in arms renown'd,
From scenes of war would oft repair;
His bed an only daughter crown'd,
And smil'd away a father's care.

By nature's happiest pencil drawn,
She wore the vernal morning's ray:
The vernal morning's blushing dawn,
Breaks not so beauteous into day.

Her breast, impatient of controul,
Scorn'd in its silken chains to lie,
And the soft language of the soul
Flow'd from her never-silent eye.

The bloom that open'd on her face,
Well seem'd an emblem of her mind,
Where snowy innocence we trace,
With blushing modesty combin'd.

To these resistless grace impart,
That look of sweetness, form'd to please,
That elegance devoid of art,
That dignity that's lost in ease.

What youth so cold could view unmov'd,
The maid, that ev'ry beauty shar'd?
Her Armine saw; he saw, he lov'd,
He lov'd—alas! and he despair'd!

Unhappy youth! he sunk oppress'd,
For much he labour'd to conceal
That gentlest passion of the breast,
Which all can feign, but few can feel.

Ingenuous fears suppress'd the flame,
Yet still he own'd its hidden power;
With transport dwelling on her name,
He sooth'd the solitary hour.

"How long," he cry'd, "must I conceal
"What yet my heart could wish were known?
"How long the truest passion feel,
"And yet that passion fear to own?

"Ah! might I breathe my humble vow!
"Might she too deign to lend an ear!

" Elvira's self should then allow
" That Armine was at least sincere.

" Wild wish ! to deem the matchless maid,
" Would listen to a youth like me,
" Or that my vows could e'er persuade,
" Sincere and constant though they be.

" Ah ! what avails my love or truth ?
" She listens to no lowly swain ;
" Her charms must bless some happier youth,
" Some youth of fortune's titled train.

" Then go, fallacious hope ! adieu !
" The flattering prospect I resign !
" And bear, from my deluded view,
" The bliss that never must be mine.

" Yet will the youth, who e'er he be,
" In truth or tenderness excel ?
" Or, will he on thy charms like me
" With fondness never-dying dwell ?

" Will he with thine his hopes unite ?
" With ready zeal thy thoughts improve ?
" With fond attention and delight,
" Each wish prevent, each fear remove ?

" Will he, still faithful to thy charms,
" For constant love be long rever'd ?
" Nor quit that bliss within thy arms,
" By every tender tie endear'd ?

" What though his boastful heart be vain
" Of all that birth or fortune gave ?
" Yet is not mine, though rude and plain,
" At least as noble and as brave ?

" Then be its tender suit preferr'd !
" Its tender sighs Elvira hear !
" In vain I sigh—but sigh unhear'd ;
" Unpity'd fal s this lonely tear !"

Twice twelve revolving moons had past ;
Since first he caught the fatal view ;
Unchang'd by time his sorrows last,
Uncheer'd by hope his passion grew.

That passion to indulge he sought,
In Raymond's groves, the deepest shade;
There fancy's haunting spirit brought
The image of his long-lov'd maid.

But, hark! what more than mortal sound
Steals on attention's raptur'd ear!
The voice of harmony around
Swells in wild whispers soft and clear.

Can human hand a tone so fine
Sweep from the string with touch profane?
Can human lip with breath divine
Pour on the gale so sweet a strain?

'Tis she—the source of Armine's woe—
'Tis she—whence all his joys must spring—
From her lov'd lips the numbers flow,
Her magic hand awakes the string.

Now, Armine, now thy love proclaim,
Thy instant suit the time demands;
Delay not—tumult shakes his frame!
And lost in ecstacy he stands!

What magic chains thee to the ground?
What star malignant rules the hour,
That thus in fix'd delirium drown'd,
Each sense intranc'd hath lost its power?

The trance dispel! awake! arise!
Speak what untutor'd love inspires!
The moment's past—thy wild surprise
She see, nor unalarm'd retires.

" Stay, sweet illusion! stay thy flight!
" 'Tis gone! Elvira's form it wore—
" Yet one more glimpse of short delight!
" 'Tis gone—to be beheld no more!

" Fly, loit'ring feet! the charm pursue,
" That plays upon thy hopes and fears!
" Ha! no illusion mocks my view;
" 'Tis she—Elvira's self appears!

" And shall I on her steps intrude?
" Alarm her in these lonely shades?
" O stay, fair nymph! no ruffian rude
" With base intent your walk invade.

"Far gentler thoughts—" his fault'ring tongue,
By humble diffidence restrain'd,
Paus'd in suspence—but thus ere long,
As love impell'd, its power regain'd.

"Far gentler thoughts that form inspires;
"With me far gentler passions dwell;
"This heart hides only blameless fires,
"Yet burns with what it fears to tell.

"The fault'ring voice that fears controul,
"Blushes that inward fires declare,
"Each tender tumult of the soul
"In silence owns Elvira there."

He said; and as the trembling dove,
Sent forth to explore the wat'ry plain,
Soon fear'd her flight might fatal prove,
And sudden sought her ark again.

His heart recoil'd; as one that ru'd
What he too hastily confest,
And all the rising soul subdu'd,
Sought refuge in his inmost breast.

The tender strife Elvira saw
Distrest; and as some parent mild,
When arm'd with words and looks of awe,
Melts o'er the terrours of her child.

Reproof prepar'd and angry fear
In soft sensations died away:
They felt the force of Armine's tear,
And fled from pity's rising sway.

"That mournful voice, that modest air,
"Young stranger, speak the courteous breast.
"Then why to these rude scenes repair,
"Of shades the solitary guest?

"And who is she, whose fortunes bear
"Elvira's melancholy name?
"O may those fortunes prove more fair,
"Than her's, who sadly owns the same!

"Ah! gentle maid, in mine survey
"A heart," he cries, "that's your's alone!
"Long has it own'd Elvira's sway,
"Tho' long unnotic'd and unknown.

"On Sherwood's old heroic plain,
"Elvira grac'd the festal day,
"There, foremost of the youthful train,
"Her Armine bore the prize away.

"There first that form my eye survey'd,
"With future hopes that fill'd my heart;
"But ah! beneath that frown they fade—
"Depart, vain, vanquish'd hopes! depart."

He said; and on the ground his eyes
Were fix'd abash'd: the attentive maid,
Lost in the tumult of surprise,
The well-remember'd youth survey'd.

The transient colour went and came,
The struggling bosom sunk and rose,
The trembling tumults of her frame
The strong-conflicting soul disclose.

The time, the scene, she saw with dread,
Like Cynthia setting glanc'd away,
But scatter'd blushes, as she fled,
Blushes, that spoke a brighter day.

A friendly shepherd's neighbouring shed
To pass the live-long night he sought,
And hope, the lover's downy bed,
A sweeter charm than slumber brought.

On ev'ry thought Elvira dwelt,
The tender air, the aspect kind,
The pity that he found she felt,
And all the angel in her mind.

No self-plum'd vanity was there,
With fancy'd consequence elate;
Unknown to her the haughty air
That means to speak superior state.

Her brow no keen resentments arm,
No swell of empty pride she knew,
In trivial minds that take the alarm,
Should humble love inspire to sue.

Such love, by flattering charms betray'd,
Shall yet, indignant, soon rebel,
And, blushing for the choice he made,
Shall fly where gentler virtues dwell.

'Tis then the mind, from bondage free,
And all its former weakness o'er,
Asserts its native dignity,
And scorns what folly priz'd before.

The scanty pane, the rising ray
On the plain wall in diamonds threw;
The lover hail'd the welcome day,
And to his fav'rite scene he flew.

There soon Elvira bent her way,
Where long her lonely walks had been,
Nor less had the preceding day,
Nor Armine less endear'd the scene.

Oft, as she pass'd, her rising heart
Its strongest tenderness confes'd,
And oft she lingered to impart,
To some soft shade, her secret breast.

" How slow the heavy hours advance,"
She cry'd, " since that eventful day,
" When first I caught the fatal glance,
" That stole me from myself away!

" Ah! youth belov'd! tho' low thy birth,
" The noble air, the manly grace,
" That look, that speaks superior worth,
" Can fashion, folly, fear, erase?

" Yet sure from no ignoble stem
" Thy lineage springs, though now unknown:
" The world censorious may condemn,
" But, Armine, I am thine alone.

" To splendour only do we live?
" Must pomp alone our thoughts employ?
" All, all that pomp and splendour give
" Is dearly bought with love and joy!

" But oh!—the favour'd youth appears—
" In pensive grief he seems to move;
" My heart forebodes unnumber'd fears;
" Support it, pity, virtue, love!

" Hither his foot-steps seem to bend—
" Come, resolution, to my aid!

" My breast what varying passions rend!
" Averse to go—to stay afraid!"

" Dear object of each fond desire
" That throbs tumultuous in my breast!
" Why with averted glance retire?
" At Armine's presence why distrest?

" What though he boasts no titled name,
" No wide extent of rich domain?
" Yet must he feed a fruitless flame,
" Must truth and nature plead in vain?"

" Think not," she said, " by forms betray'd,
" To humbler worth my heart is blind;
" For soon shall every splendour fade,
" That beams not from the gifted mind.

" But first thy heart explore with care,
" With faith its fond emotions prove,
" Lurks no unworthy passion there?
" Prompts not ambition bold to love?"

" Yes lovely maid," the youth replies,
" A bold ambition prompts my breast,
" The tow'ring hope that love supplies,
" The wish in blessing to be blest.

" The meaner prospects I despise
" That wealth, or rank, or pow'r bestow;
" Be your's the grov'lling bliss ye prize,
" Ye sordid minds, that stoop so low!

" Be mine the more refin'd delights
" Of love, that banishes controul,
" When the fond heart with heart unites,
" And soul's in unison with soul."

Elvira blush'd the warm reply,
(To love a language not unknown)
The milder glories fill'd her eye,
And there a softer lustre shone.

The yielding smile, that's half supprest,
The short quick breath, the trembling tear,
The swell tumultuous of the breast,
In Armine's favour all appear.

At each kind glance their souls unite,
While loves soft sympathy imparts
That tender transport of delight,
That beats in undivided hearts.

Respectful to his lips he prest
Her yielded hand ;—in haste away
Her yielded hand she drew distrest,
With looks that witness'd wild dismay !

" Ah ! whence, fair excellence ! those fears ?
" What terror unforeseen alarms ?
" See where a father's frown appears"——
She said and sunk into his arms.

" My daughter !—Heav'ns !—it cannot be—
" And yet it must—O dire disgrace !
" Elvira have I liv'd to see
" Clasp'd in a peasant's vile embrace !

" This daring guilt let death repay"——
His vengeful arm the javelin threw ;
With erring aim it wing'd its way,
And far, by fate averted, flew.

Elvira breathes—her pulses beat,
Returning life illumes her eye ;
Trembling a father's view to meet,
She spies a reverend hermit nigh.

" Your wrath," she cries, " let tears assuage,
" Unheeded must Elvira pray !
" O let an injur'd father's rage
" This hermit's sacred presence stay !

" Yet deem not, lost in guilty love,
" I plead to save my virgin fame ;
" My weakness virtue might approve,
" And smile on nature's holy flame."——

" Oh ! welcome to my hopes again,
" My son,"—the raptur'd hermit cries,
" I sought thee sorrowing on the plain,"
And all the father fill'd his eyes.

" Art thou," the raging Raymond said,
" Of this audacious boy, the sire ?

"Curse on the dart that idly sped,
"Nor bid his peasant soul expire?"
"His peasant soul!"—indignant fire
Flash'd from the conscious father's eye,
"A gallant Earl is Armine's sire,
"And know, proud chief, that Earl am I.

"Tho' here within the hermit's cell,
"I long have liv'd unknown to fame,
"Yet crouded camps and courts can tell—
"Thou too hast heard of Egbert's name.

"Ha! Egbert!—he, who tyrant rage
"Forc'd from his country's bleeding breast?
"The patron of my orphan age,
"My friend, my warrior, stands confest!"

"But why?"—"The painful story spare,
"That prostrate youth," said Egbert, "see;
"His anguish asks a parent's care,
"A parent, once who pity'd thee!"

Raymond, as one, who glancing round,
Seems from some sudden trance to start,
Snatch'd the pale lovers from the ground,
And held them trembling to his heart.

Joy, gratitude, and wonder shed
United tears for Hymen's reign,
And nature her best triumph led,
For love and virtue join'd her train.

DESULPHURATION OF METALS.

Memoir upon the De-sulphuration of Metals. By M. GUENIVEAU, *Engineer of Mines.* 31 *Phil. Mag.* 213.

AMONG the number of metallic sulphurets which nature presents to us, there are several the decomposition of which is very important in the arts: the sulphurets of iron, copper, lead, mercury, &c., give place to metallurgical processes highly deserving of the attention of chemists.

The nature and properties of these compounds are well known, since chemists have so frequently made them an object of enquiry. The facts, however, collected in laboratories have never been carefully compared with those furnished by the workshops, although it is very well known that the latter description of experiments furnish the most useful results; and the theory of various operations to which we subject the sulphurets, has not kept pace with the relative progress of science. It is my intention, in the Memoir, to supply what is wanting in this respect: for this purpose, I have made various experiments, and collected several observations long known: to these I have added some reflections peculiar to myself, and have deduced from their examination, consequences which may be productive of some changes in the ideas generally entertained respecting the treatment of the metallic sulphurets.

§ *Of the Action of Heat upon the metallic Sulphurets.*

The action of *heat* upon the metallic sulphurets should be first examined, because it is to be met with in all the operations by which we seek to decompose these substances: in order to appreciate it in a precise manner, I have made choice of experiments and observations in which this action is entirely isolated, which is worthy of observation; for it is because we have not analysed the effects produced by several causes, that we have been led, in metallurgy, to ascribe to *caloric alone* a de-sulphurating power, which it does not seem to possess in any great degree.

The sulphurets of mercury and of arsenic are volatilized in close vessels, when they are exposed to a temperature somewhat raised. The sublimed sulphuret is frequently altered in its colour; and the experiments of Messrs. Proust and Thenard, show that this change is the consequence of a variation in the proportion of the elements of this compound.

The native sulphuret of iron (pyrites of iron) undergoes a partial decomposition only from the caloric: by distilling it in a retort, we cannot extract from it the half of the sulphur which it contains*. In Saxony, the distillation of pyrites upon a large scale never yields more than from 13 to 14 per cent. of sulphur†.

These facts not being sufficient to decide my opinion upon the effects of heat, because all the experiments which have come to

* Proust, *Journal de Physique*, tome liii.

† *Schlutter*, tome ii. p. 228, of the French translation.

my knowledge were made at a temperature a little raised, I proceeded in the following manner: I put into a crucible, pyrites of iron pulverized: covered it with charcoal in powder, and heated it in the forge for an hour; I found a mass still preserving all the characters of pyrites: it seemed to have been completely melted, and retained two thirds of the sulphur contained in the natural pyrites. This experiment being repeated, left me in no uncertainty upon the effects of heat *by itself*, upon sulphuret of iron, and I thought I might conclude, that, whatever be the temperature, these effects produce a partial decomposition.

Sulphuretted copper and pyritous copper, submitted to the action of heat, produce effects analogous to those observed with respect to iron: the distillation of the pyritous copper furnished but very little sulphur: these two kinds of minerals of copper may in short be considered as mixtures of the sulphurets of copper and of iron, and the sulphur which heat separates from it, proceeds almost entirely from the sulphuret of iron.

The sulphuret of lead, or galena, is one of those minerals the treatment of which was most various: all chemists agree in regarding it as composed of sulphur and lead only, in the proportion of 15 of the former, and 85 of the latter. I was the more careful in observing the effects of caloric upon the galena, because, by trying to separate the sulphur from it by this agent, I expected to obtain lead in a metallic state, the weight and fusibility of which render the re-union very easy. It was, besides, very easy for me to operate without the contact of atmospheric air.

I put into a retort 30 grammes of galena reduced to powder, which I heated for two hours, but not so strongly as to make it agglutinate: a very little sulphuric acid only was disengaged, produced by the action of the air of the vessels, and I perceived no sulphur sublimed at the neck of the retort. I increased the fire for about two hours more, until the galena and the vessel which contained had undergone a kind of fusion. The sulphur volatilized in this second part of the operation was in so small a quantity that it was not possible for me to detach and weigh it: the residue was of a metallic lustre; it was agglutinated, and did not contain an atom of ductile lead*.

* There are few chemists who have not made this experiment with similar results. I may here remark, that if the heat had been long enough continued, and in the open air, the *galena* would have been completely roasted.

The heat not having been very strong in this experiment, I submitted to the fire of a forge some pulverized galena, placed in a crucible, and covered with charcoal in powder. I found a mass which had been melted, and similar to what is called *matte de plomb* by the French metallurgists; there was no lead free from sulphur, but only some parts of the button were a little ductile. Analysis convinced me that there remained about three fifths of the sulphur contained in the galena. I attributed a part of the loss of 27 per cent. which it had undergone by the action of the fire, to the volatilization of the sulphuret of lead itself; for the loss owing to the separation of the sulphur could not exceed six per cent. at most.

The galena therefore undergoes but a very incomplete decomposition from heat.

I shall not particularize the sulphurets of zinc, antimony, &c. because I do not know a sufficient number of experiments for determining, in a certain manner, the effects which heat produces upon them: analogy, however, inclines me to think that it does not completely decompose them.

All the facts I have presented seem to me to establish, that the action of caloric alone upon the metallic sulphurets, and particularly of those upon iron, copper, and lead, is confined to their taking from them a small portion of the sulphur which they contain, and afterwards in melting and volatilizing them.

§ II. *Of the simultaneous Action of Heat, and Atmospheric Air upon the metallic Sulphurets.*

The metallurgic operation which has for its object the de-sulphuration of the metals is known by the name of *roasting*. Most of the authors who have spoken of it do not seem to have recognized any other agent in the decomposition except caloric; and even those who since the new chemical theories have remarked the influence of the atmospheric air, have never regarded it as essential*. The experiments I have detailed having shewn how the action of heat alone is insufficient for decomposing a metallic sulphuret, we must necessarily ascribe to the oxygen of the atmosphere the greatest share in the de-sulphuration of the metals by *roasting*. The affinities of sulphur and of metallic substances for

* Macquer, in this respect, agrees with the metallurgists. We find in his Dictionary of chemistry the following passage: "There are several methods of separating sulphur from metallic substances: in the first place, as sulphur

this principle render this assertion very probable ; it is besides proved by the chemical examination of the produce of all the roasting, as well as by the way in which the operation is conducted. In place of seeing in the roasting of the sulphurets the volatilization of the sulphur, produced *by a well-managed heat*, it will be the decomposition of a sulphuret by the simultaneous action of the air and of caloric : and the well known necessity of not melting the ores does not seem to be recommended in consequence of the fear of communicating to it, together with liquidity, a force of cohesion which will oppose the separation of the sulphur ; but rather because this state will confine the action of the air to a surface, which, not being capable of being renewed, will be soon covered by the metallic oxyd. The combination of the oxygen with the elements of the sulphurets, gives birth to oxyds and to acids, the affinities of which have great influence upon the separation of the sulphur, and the results of a roasting : the lattter generally present a mixture of oxyd, of sulphat, and of indecomposed sulphuret. I shall examine separately and in detail the roasting of several kinds of sulphurets, because the nature of the metal produces great modifications in their results ; and shall presently show, why, and in what form, the sulphur is separated.

Roasting of Pyritous Copper.

We arrange pieces of pyritous copper upon faggots, in such a way as to make the combustion continue a long time. The first application of the heat separates a part of the sulphur, which is distilled in some measure, and may be collected ; but afterwards it is this combustible which serves, upon burning, to continue the operation : sulphureous acid is liberated, the elasticity of which, increased by the elevation of the temperature, hinders its combination with the metallic oxyds. The sulphuric acid which is formed, in spite of the care taken to slacken the combination, is united to the oxyds of copper and iron, but the sulphate of iron is partly decomposed by the hyper-oxydation of the metal.

The pyrites of iron submitted to the same operation undergoes *analogous decompositions*, the succession of which is in every respect the same.

is volatile, and as these substances are fixed, or at least not so volatile as sulphur, the *action of heat alone is sufficient* to take the sulphur from most metals." He seem, however, to have been aware of the importance of the contact of the atmospheric air in roasting, since he says, when speaking of the sulphurets of mercury and of arsenic, " It will be possible to desulphurate them without intermedium, by a well-managed heat and *in the open air.*"

The roasting of pyritous copper in the reverberatory furnace produces the same phænomena, and seems as if it would admit of a much more complete separation of the sulphur, than that produced in the open air. If it were not so, it would no doubt be owing to the difficulty of hindering the agglutination of the sulphuret produced by the elevation of temperature, owing to the rapid and inevitable combustion of a great quantity of sulphur.

I come now to speak of a furnace, in which we effect at the same time both the melting and the roasting (to a certain degree) of pyritous copper: this is the method practised at Falhun in Sweden,* and is done with an inner crucible, which receives the produce of a flux of 24 or 48 hours, and in which a separation, or rather a combustion, of the sulphur takes place. The wind of the bellows passes over the surface with sufficient force for removing the scoriæ, and burning a part of the sulphur on the surface: the iron is thus oxydized, and quartz is added in order to vitrify it in proportion as the roasting goes on.† It is thus that

* We find the following observations in the *Voyages Metallurgiques*, by Jars, tome iii. pages 55 & seq. "The flux of the mineral roasted *a single time*, is effected in a furnace which has an inner bason destined to contain the produce of the operation."—"When it is heated, it is charged with a good deal of scoriæ from the flux of black copper, with quartz and a little mineral." "They do not mix the *quartz* with the mineral, but only add it when there are any fears of mischief in the inner bason."—"The fusion of the roasted pieces (*mattes*) is effected in the same kind of furnace, but smaller."—"The substances must remain a longer time in the furnace, which must not be opened until the end of twice twenty-four hours. They then extract a very few *rich mattes*, but a very large pig of black copper."—"This method of melting the pyrites is certainly the only one that can be used, and which, in spite of the inconveniences it presents, may nevertheless be advantageous." "Another very precious advantage is a *concentration* of the metal contained in the *fluid matter which is continually agitated by the wind of the bellows.* They extract a smaller quantity of *mattes*, but they are richer. We confess our surprise at the flux of black copper, when we see the small quantity of rich *mattes* which comes from a very inferior sort of ore, and which does *not even seem to have been roasted.*" We should be of M. Jars' opinion, that this method of melting pyritous copper is one of the best, if more copper was not volatilized than by the other process: but if, as I think, we may substitute the *reverberatory furnace* for that used at Falhun, and in other respects following up the same series of operations, there would certainly be great advantages derived over fusion in the hand furnace.

† Swedenborg (*de cupro*) thus expresses himself: "*Plurima ejus ars* (meaning the melters) *in eo consistit, ut lapidem siliceum, justo tempore et modo, sciat offerre.*"

we may explain the concentration of the metal, and the general result of the flux, which surprised M. Jars very much. This process is perhaps the only one in which, at the same time, the sulphur and iron are separated in any quantity.

The de-sulphuration of pyritous copper by roasting is, in my opinion, produced, 1st, by the sublimation of a small portion of sulphur, which may be collected or burnt in the air: 2dly, by the extrication of sulphurous acid, so much the more abundant as the operation is well conducted:* 3dly, by the vaporization of a little sulphuric acid, the greatest part of which, however, remains united to the copper.

Roasting of Galena.

IT is extremely difficult completely to desulphurate galena by *roasting:* the affinity of its component parts for oxygen does indeed effect the disunion quickly enough; but that of the new compounds, *the sulphuric acid and the oxide of lead*, gives birth to a new combination, which retains the sulphur, and thus forms an obstacle to the desulphuration: to this same affinity of the oxide of lead for the sulphuric acid, we must attribute the facility with which this acid is formed in the roasting of galena.

I shall examine in detail the various processes to which this important decomposition gives rise, as I think they will explain numerous and complex phænomena.

Whatever care is taken in roasting galena, it is impossible to convert all the sulphur into sulphurous acid, and to avoid the formation of sulphuric acid; the result always gives a mixture of oxide and of sulphate of lead.

In roastings performed upon a large scale, and in a regulated atmosphere, the proportion of sulphate of lead is much more considerable, it is regulated by the temperature and by the facility with which the air penetrates the ore; numerous experiments made in *l' Ecole des Mines* incline me to think that the roasted *schlich* of the Pezey ore contains half its weight of sulphate of lead; whence it follows, that even supposing the whole galena to be decomposed, the roasting has not separated the half of the sulphur it contains.

* Recent experiments of Messrs. Clements and Desormes show, that the combustion of sulphur does not produce sulphuric acid so easily as imagined: but we know that its formation is determined by various peculiar circumstances, such as the presence of the alkalies, oxyds, &c.

The reverberating furnace may be employed with great success in roasting the sulphurized ores of lead. In some foundries, they produce in this kind of furnace so complete a separation of the sulphur, that it is sufficient, when the roasting is supposed to be finished, to add some charcoal, in order to obtain instantaneously a great quantity of metallic lead. It cannot be doubted, however, that a great quantity of sulphate of lead is formed; which, as we have already seen, is a necessary result of the action of the air upon galena exposed to a high temperature; the chimneys of the furnaces are likewise filled with the above substance: the decomposition of this sulphate by charcoal produces a sulphuret or a *matte* of lead; and although sulphurous acid may be disengaged, it is very difficult to explain why the addition of charcoal makes *the lead* flow instantly in a considerable quantity. I thought that the sulphate of lead was decomposed during the roasting, and that nothing remained after this operation, but an oxide a little mixed; and I thought I discovered the cause of this decomposition in the action of the galena, as yet undecomposed, upon the sulphate formed. The following experiments will show the nature and result of this action.

I put into a retort a mixture composed of one part of pulverized sulphuret of lead, and three of sulphate*, and I heated it at first but slowly. When the retort was red-hot, a considerable disengagement of sulphurous acid gas took place which lasted an hour, when the retort melted; the residue presented a mixture of oxide and of sulphate of lead. I ascertained that the sulphurous acid which had been collected in the water was not mixed with sulphuric acid.

This experiment demonstrates in an indisputable manner the decomposition of the sulphate of lead by the sulphuret, or rather that of the sulphuric acid which it contains, by the sulphur and the lead of the galena. The sulphurous acid certainly proceeds both from the oxygenation of the sulphur, and from the demi-decomposition of the acid, as I am convinced that no sulphate remained in the residue. I repeated this decomposition, employing equal parts of galena and of sulphate; the sulphurous acid disengaged was more abundant, and there remained in the retort a mixture of oxyd and of sulphuret; from which I concluded, that if, in the first experiment, the proportion of sulphuret of lead was too weak,

* This mixture was made in the humid way.

it was too strong in the latter. I also made another attempt to attain some proportions rigorously sufficient for the mutual decomposition, and endeavoured at the same time to assure myself of the oxydation of the lead contained in the galena in a metallic state. I put fourteen grammes of sulphate, well mixed with eight grammes of sulphuret, in a crucible, which I allowed to become red-hot in a gradual manner. I remarked that a considerable crackling was produced, occasioned by the disengagement of the sulphurous acid. I did not take the crucible from the fire until I saw its contents melted. I found two substances well separated; the one occupying the bottom of the crucible was merely melted sulphuret of lead, without any mixture of *ductile lead;* the other presented all the characters of the oxyd of lead called *glass of lead;* this part was a combination of oxyd and *silex*, proceeding from the materials of the crucible, without any marks of sulphate of lead.

This experiment proved that the lead of the galena was oxydated at the expense of the sulphuric acid; but it did not show the quantity of galena necessary to the complete decomposition of the sulphate. I am of opinion, however, that the proportion of *one part* of the former to two of the latter is sufficient; besides, it closely resembles the proportion which calculation gives us of the composition of these substances.

The following are the natural consequences of these facts: 1st. The galena and the sulphat of lead are mutually decomposed at a high temperature. 2d. This decomposition gives place to the formation and to the disengagement of a great quantity of sulphurous acid, and consequently to the separation of a considerable portion of the sulphur contained in the ore.* 3d. The result is oxyd of lead, when the proportions are proper; and in the contrary case a mixture of oxyd and of sulphat, or oxyd and galena. The application of these consequences to the roasting of the sulphuret of lead in this reverberating furnace is very easy. I shall explain the theory of this operation in the way I conceive it.

The pulverized galena, or the *schlich* of lead, spread out upon the floor of the furnace in a layer of a few inches in thickness,

* If we admit that a mixture of *one* part of sulphuret and two of sulphate are entirely decomposed and reduced to oxyd of lead, the quantity of sulphur separated will be two-fifths: so that one part of sulphate, in an indefinite quantity of galena, will separate one-fifth of sulphur; and one of sulphuret in sulphate will separate three-fifths.

the upper part of which is exposed to the action, produces the phænomena usually observed in the common roastings. The heat vaporises a little sulphur; the air converts that part upon which it acts into sulphurous acid, which is liberated; but a much greater part is converted into sulphuric acid, which is combined with the lead oxydated at the same time. The ores are stirred; the sulphate of lead is mixed with the undecomposed schlich, and their decomposition produces sulphurous acid; the surface of the layer which has been renewed, reproduces sulphate, which afterwards serves to produce a new disengagement of gas, and thus continues the desulphuration, to which we find there is no end except the complete decomposition of the galena. If the operation has been well managed, and if too much sulphate of lead has not been formed, the result of the roasting will be almost pure oxyd of lead; in the contrary case, some sulphate will probably remain, which charcoal will bring back to the state of sulphuret, and the decomposition of which will take place like that of the galena. We may judge from this detail, how important it is to avoid melting the sulphuret of lead subjected to roasting; for the action of the air upon the melted ore will soon be rendered null by the formation of the oxyd of lead which will cover it; and the sulphate of lead not being capable of being any longer mixed with the galena, there will be no method left of desulphuration.

The roasting of galena in the reverberating furnace is therefore reduced to the conversion of the sulphur which it contains into *sulphurous acid*; and as it is produced in a great measure by the intermedium of the sulphate of lead which is continually formed, this process admits of a much more complete desulphuration than the others.

The same decomposition of the sulphuret of lead by the sulphate, in my opinion, takes place also in the treatment of the ores of lead in what are called Scotch furnaces: in Scotland they roast and melt galena by one uninterrupted operation, employing coal and turf.

This kind of furnace is employed with success in the mine at Pezey, in melting *roasted* galena containing at least one-third of its weight of sulphate of lead. It gives no *mattes* as a final result, which proves that it admits of the decomposition of the sulphat and the separation of the sulphur contained in it. I am of opinion that the action of the portion reduced to the state of *sulphuret* by

the contact of the coals upon the undecomposed sulphate, is one of the principal causes of the desulphuration produced.

We have had occasion to speak of several kinds of furnaces, (the Fahlun and Scotch furnaces among the rest,) in which the metallic sulphurets will undergo a real roasting; but there are others where this effect is scarcely perceptible. I consider the present as a proper opportunity for introducing some reflections, upon the differences they exhibit in this respect. They ought to excite the more interest, because they are intimately connected with the present subject, and explain some phænomena which cannot be accounted for from the way in which the operation of roasting has generally been regarded.

It is a well-known fact, in foundries, that the highest furnaces are those which admit of desulphuration the least, or, in the language of the workmen, they produce the most *mattes*. If a convincing proof of this is wanted, it will be sufficient to mention, that at Pezey there have been seen roasted ores of lead, containing a great deal of sulphate of lead, the flux of which, in the Scotch furnace, gave no *mattes*, and yet they produce a great quantity when they are passed to the common furnace.

If heat alone decomposes easily and completely the metallic sulphurets, the upper part of the high furnaces will be very proper for operating the roasting of ores; for besides the temperature being a little elevated, the air which ascends to that height, being deprived of a part of its oxygen, forms very little more of these sulphates which are opposed to the separation of the sulphur: but it is quite different, and in my eyes it is a new proof of the little effect of the action of caloric alone upon substances. The sulphur is separated from the sulphurets, as we have seen, in the state of sulphurous acid, and oxygen is indispensable to its formation. In furnaces not much raised, the air which touches the ore recently thrown in, still contains a great deal of oxygen; the sulphurous acid formed is soon subjected to the deoxydating action of the coals; if there be a small portion of it decomposed, a new sulphuret is formed, which is afterwards roasted like the mineral. In the Scotch furnace, for example, when *mattes* are melted, they are thrown successively into the furnace, and what has escaped one operation is decomposed by a second. In high furnaces, on the contrary, the ores placed in the upper part undergo but a very imperfect desulphuration, because the air which comes in contact with it contains but very little free oxygen, the sulphurous acid

formed in the interior is in a great measure decomposed by traversing the whole height of the furnace filled with coals, and the sulphuret is recomposed; the latter tends by its gravity to gain the basin, where it does not arrive until after a series of decompositions, which cannot take place, as we have in fact observed, without there resulting a considerable loss in metal.

All these facts seem to leave no doubt as to the following proposition: The decomposition of the metallic sulphurets by roasting is produced by the oxygenation of its compounds, and the sulphur is separated more or less completely in the state of sulphurous acid.

III. *Desulphuration of the Metals independent of the Action of the Air.*

The varied affinities of sulphur for different mineral substances, furnish the means of decomposing certain sulphurets; and several have been employed in metallurgy with success. In order that the decomposition of a metallic sulphuret by any mineral should form the basis of a metallurgic process, it is not sufficient that the affinity of this mineral for sulphur should be greater than that of the metal; it must, besides the conditions required by economy, also possess several other requisites absolutely necessary for the success of the operation, which considerably limit the number of the agents pointed out by chemistry: for instance, if the sulphuret resulting from the decomposition is not fusible, or but very little so, if it has the property of combining with the metal required to be separated, or rather with the still undecomposed sulphuret, it is evident that we cannot effect our purpose, namely, the isolation of the metallic substance. Hitherto little else has been used except *lime* and *iron*.

Desulphuration of Mercury.—It is very easy to decompose the sulphuret of mercury; it being sufficient if we present to the sulphur a substance capable of retaining it, and volatilize the mercury alone. It is thus that iron and lime are employed together or separately in the treatment of the ores of cinnabar.

Desulphuration of Copper.—Pyritous copper is melted in some foundries with lime, either in the common or the reverberating furnace; but the process is not well enough known as yet to enable us to judge of the efficacy of lime as an agent in this case.

I was once of opinion, with some metallurgists, that the well known superior affinity of iron for sulphur over that of copper for

the same combustible, might determine the decomposition of the *sulphuret of copper* by this metal, at least in certain cases. The following experiments, however, did not warrant me in continuing of this opinion.

First Experiment.—I made a mixture of ten grammes of pyritous copper, the composition of which I knew, with four grammes of iron filings : I put this into a crucible, covered with charcoal in powder, and heated it in the forge for three quarters of an hour. The proportion of the iron had been calculated so accurately that it was sufficient for taking up all the sulphur combined with the copper in the mineral employed. I found in the crucible a perfectly homogeneous mass, weighing thirteen grammes, which did not contain *the smallest globule of metallic copper*, nor any appearance of *separation*, between the *sulphuret of iron* and that *of copper**.

Second Experiment.—Another trial was made by employing ten grammes of pyritous copper and five grammes of the same *roasted* mineral. This is nearly the case with the fluxes in which the ore or the *mattes* are not completely desulphurated ; the proportion of the iron was still sufficient for separating copper, which was very abundant in the mixture. I kept up the heat for three quarters of an hour, and found, as in the preceding experiment, a homogeneous mass, without any trace of metallic copper, nor of pure sulphuret of copper ; this was a real *matte* of copper.

Third Experiment.—On this occasion an equal mixture of crude pyritous copper, and roasted copper, dipped in olive oil, and heated strongly for half an hour in a crucible, presented nothing but a powder, which had not undergone fusion, on account, without doubt, of the superabundance of the iron.

I think these few experiments are sufficient for proving that the *desulphuration* of copper by means of iron will be always very difficult, because there is formed *a triple combination between the sulphur, iron and copper*, or rather a combination between *the sulphurets of copper and of iron*, which prevents the separation of the copper.

Dusulphuration of Galena.—This is one of the sulphurets which best yields to the decomposition in question ; the fusibility of the lead which facilitates its aggregation, as well as the little affi-

* In the decomposition of *galena* by *iron*, we observe, when the latter is in too small quantity, three distinct substances of lead, sulphuret of lead, and lastly, sulphuret of iron in the upper part.

nity it has for sulphur, are the causes of the successful trials that have been made on this subject. *Lime* and *iron*, are employed in various circumstances in the desulphuration of galena; the use of lime is not very general, and it is impossible to judge of its effects from what is known of the properties of the sulphuret of lime. The treatment of galena by *iron* is more in use, and appears more advantageous.

The above memoir will, I hope, suggest several experiments to those who are engaged in metallurgical pursuits.

All the experiments I have detailed were performed in the laboratory belonging to the Council of the Mines, and under the eyes of M. Decostils, by whose superior judgment I profited considerably during the progress of my labours.

Notes to aid in the analysis of mineral waters: by the Editor.

Substances held in solution.	*Reagents or Tests.*
A general idea of the quantity of dissolved salts.	A solution of soap in Alcohol.
Uncombined acid in general.	Paper dyed blue with Litmus slightly alkalized.
Sulphuric acid in particular.	Water (hydrat) of Barytes or Strontian: or by the muriats of these earths.
Uncombined Alkali.	Blue Litmus paper slightly reddened by a weak acid.
Ammonia in particular.	Nitrat of Mercury.
Sulphuric acid in sulphats.	Muriat of Barytes or Strontian.
Nitric acid in nitrats.	The deflagration of the nitrats: or by the smell on decomposing them with sulphuric acid.
Muriatic acid in muriats.	By decomposing them by means of sulphuric acid and attending to the odour: by nitrat of silver: by sulphat of silver where there are sulphats also in the solution: by nitrat of mercury: also, almost all the salts can be separated from the sulphats by boiling in strong alcohol, which will not dissolve the sulphats. See 2 Hen. ch. 206.

	DISCOVERED BY.
Carbonic acid.	Lime water: acetat of lead.
Alkaline carbonats.	Litmus paper: muriat of lime: nitrat of lime.
Silex or Silica.	The residuum rough to the touch, after solution in acids; The solubility of that residuum in pure potash.
Alumina.	Carbonat of Ammonia, the precipitate insoluble in acetic acid: succinat of ammonia, which does not throw down magnesia.
Magnesia and Lime in a muriatic solution.	Are separated by the gradual and cautious addition of concentrated sulphuric acid by small drops; the sulphat of lime gradually falls down: or by the next process.
Lime, magnesia and alumina in a muriatic solution.	Are separated from a muriatic solution thus. Throw down the lime by cautiously adding oxalat of ammonia: throw down the alumine by the cautious addition of carbonat of ammonia not in excess; or of succinat of ammonia: throw down the magnesia by adding to the warm solution, a warm solution of carbonat of potash: or by adding phosphat of soda, to the solution containing carb. of ammonia. See 2 Hen. 332 for the component parts of ammoniaco phosphat of magnesia.
Lime (Calcia.)	Oxalic acid: oxalat of amm: oxal. potass: sulphuric acid: but int his last case 500 grains of water will hold in solution at least one grain of gypsum.
Baryta. Strontia.	Sulphuric acid same } distinguished by the red flame of Strontia.
Sulphuret of lime or alkali.	Acetat or nitrat of lead, thrown down a dirty blackish brown: the lime is thrown down by oxalic acid, and the sulphur swims
Iron generally.	Tincture of galls: infusion of galls or oak bark: prussiat of lime; triple prussiat of potash. Succinat of Amm.
Iron in carbonic acid.	The subsidence of ochre on exposure to the air for a day or two: boiling the solution: by hydrat of lime.

Iron in sulph. acid.	Hydrat of Barytes, to detect the acid.
Copper.	Digesting in carbonat of ammonia, or pure ammonia: arseniat of potass making Schule's green.
Lead or arsenic.	Hydrosulphuret of amm. sulphuret of lime or potass, (a brown black precipitate.)
Arsenic particularly.	The garlic, white, fumes on burning it: the whitening of two pieces of brass or copper, the arsenic being fastened between them.
The quantity of saline matter generally.	Gentle evaporation in a glass or china basin: evaporate if possible not less than a pint.
Sulphuric salts generally.	Their insolubility in strong boiling alcohol.
The gasses generally.	Evaporate in a glass retort with a pneumatic apparatus.
Sulphure ted hydrogen gas.	The odour: the deposition of sulphur on throwing up an acid gas: the water containing it, blackens silver and lead and their solutions.
Carbonic acid gas.	Hydrat of lime, baryta or strontia: acet. of lead.
Efflorescent salts as those with basis of soda.	Their crystals efflorescing on exposure to air.
Deliquescent salts, of the muriats.	Their crystals deliquescing on exposure to air.
Nitrats.	Their deflagration.

Component parts of many salts, to aid in the analysis of mineral waters.

Common Sulphat of Lime, contains $21\frac{1}{2}$ or 22 per. cent of water, that may be driven off by a continued full red heat. When the quantities are small, an hour's exposure to this heat is sufficient. Thus deprived of its water, it contains 42,5 lime, and 57,5 acid, on the average of the experiments of Thompson and Berthier.

One hundred grains of pure lime, will yield when saturated with sulphuric acid, 236 grains of anhydrous sulphat of lime: that is deprived of its water of crystallization by an hour's red heat. One hundred grains of carbonat of lime produce 130 grains of anhy-

drous sulphat of lime. Pure carbonat of lime containing 44½ per cent. of carbonic acid, 180 grains of it will yield 236 grains of anhydrous sulphat.

One hundred parts of carbonat of lime, yield 154 parts of sulphat of lime, compact, not crystallized, and in the state in which gypsum or plaister stone is commonly found.

One hundred parts of carbonat of lime yield 160 parts of well crystallized sulphat, per Klaproth.

Common hydrous (unboiled) gypsum contains 33,15 lime 44,85 acid, 22 water.

Sulphat of potass contains	46,62 acid,	51,38 alkali.		
soda	23,52 acid,	18,48 alkali,	58 water.	
ammonia	55 acid,	14 ammonia,	31 water.	
magnesia	33,05 acid,	16,05 magn.	50 water.	
alumina	30,52 acid,	10,5 alkali, 10,5 alumina,	48,58 wt.	
baryta	33 acid,	67 baryta.		
lead	26,5 acid,	69 lead, 5 oxygen.		
Muriat of potass	66,66 acid,	33,34 alkali.		
soda	46 acid,	54 alkali.		
ammonia	61,65 acid,	38,35 alkali.		
lime	49,23 acid,	50,77 lime.		
baryta	22,93 acid,	62,47 baryta, 14,06 wa'r.		
magnesia	56 acid,	44 magnesia.		
silver	19,05 acid,	80,95 oxyd of silver.		

See for the muriats (anhydrous) Dr. Marcet's paper on the waters of the Dead Sea. 20 Nich. Journ. 28.

Carbonat of lime	44½ acid,	55½ earth	water not noticed: included in the acid nearly.
baryta	21,75 acid,	78,25 earth	
magnesia	34 acid,	66 earth	

Nitrat of potash	48,62 acid, 51,38 alkali.	
soda	58,6 acid, 41,4 alkali: anhydrous: average of experiments.	
ammonia	74,5 acid, 19.8 alkali, 5,7 water: compact nitrat. 69,5 acid, 18,4 alkali, 12,1 water: prismatic nitrat.	
lime	57,44 acid, 32, earth, 10,56 water: (Kirwan).	
baryta	40,7 acid & water, 59,3 earth. (Thompson.)	
amm. & mag	78, nitrat magnesia, 22, nitrat of ammonia. (Fourcroy.)	
Oxalat lime common	59.2 acid, 35,05 earth, 5,03 water, (Thompson.)	
anhydrous	62,5 acid, 37,5 earth. (Thompson, 21 Nich. Jour. 328.)	

Experimenters on the composition of neutral salts, do not always attend with necessary accuracy, to the amount of water in the composition, but the preceding table is drawn up on the best modern authorities. T. C.

NOTICES.

Some time ago was announced the discovery of a whole mammoth in a frozen state on the northern coast of Russia, which has been brought to Petersburgh. The bones of an *unknown animal* were lately found in a peat moss in Russia. The creature must have been about 12 feet long: the horns were $2\frac{1}{2}$ feet long, and $1\frac{1}{2}$ foot round at the root. From the appearance of this imperfect skeleton it seems to have belonged to the URUS or AUROCHS mentioned by Cæsar in his account of Germany. Anal. Rev. June 1814.

Variation of the Compass.—A correspondent remarks that the needle which in this latitude pointed truly to the North in 1657 and has been inclining to the Westward ever since, at the average rate of ten minutes per annum has reached the utmost extent of its variation; has been stationary, and is now receding. If this be correct it seems that about 25 degrees is the extent of its variation Westward: that it will in about 150 years, again point truly to the North; and probably for the next 150 years will incline to the East, taking up a period of 500 years in making a revolution. *Ibid.*

A Steam Engine has been erected at Bristol (England) of which the principle is said to be a hollow wheel, whose interior is half filled with a fluid metal. The steam is supplied by a common boiler and makes no noise whatever, saving half the coals, &c.

Mr. Bakewell who lectures at the Surry Street Institution, proposes the application of GUNPOWDER as an impelling force in lieu of steam. A single dram of gunpowder properly applied, will rend a piece of metal equal in thickness to a large piece of ordnance. The motion might be communicated by a balance wheel and crank. *Ib.*

Mr. Accum has published a method of making IODE, the substance which at the heat of 158 of (the Centigrade?) thermometer is converted into a violet coloured gas. It was first discovered by M. Courtois, and obtained from Kelp. It is not acted on by oxygen, or charcoal: it combines with the metals and their oxyds, forming soluble compounds. It combines also with hydrogen

and phosphorus. With ammonia it forms a detonating compound. When it comes in contact with oxymuriat of sulphur it assumes a violet colour of great intensity and beauty. It may be made thus in a small way. Take the crystallizable residuum of a solution of Kelp, or of Spanish Barilla, *after* all the saline matter capable of crystallization is separated. Put a dram of this previously fused for a few minutes to free it from moisture, and reduced to a coarse powder, into a thin glass tube 10 or 12 inches long and thr e-eighths of an inch in the bore : add to it without soiling the inside of the tube, about half its weight of oil of vitriol: this may be done by sucking the acid up with the mouth in a small long glass tube drawn out to a capillary point, applying the finger to the upper orifice, and thus by means of it, transferring the acid into the larger tube. Shake the whole together and apply a gentle heat by a lamp or taper. A dense vapour will make its appearance, and a black glistening powder (Iode) will be sublimed in the colder part of the tube. Cut off by means of a file, the part of the tube which contains the Iode, and seal the extremities of it by means of a blow-pipe or a spirit lamp.

The preparation of Iode on a larger scale. Place a long, slender necked, tubulated retort in a sand bath : surround the whole body of the retort up to the tubulure with sand, and adapt without luting to the beak of it, a wide mouthed vial or receiver. Introduce through the tubulure, first one part of oil of vitriol, and then two parts of the fused saline mass before mentioned, broken into small pieces of the size of pease, and distil for a few minutes with a gentle heat. The Iode will become sublimed into the neck of the retort in a crystalline form, exhibiting a black shining crust. Cut off the neck of the retort with a file, and collect the Iode by means of a feather or camel's-hair brush.

If the whole of the saline mass of kelp or barilla, freed from carbonat of soda only, and which of course contains muriat of soda, muriat of potass, sulphat of potass, hydrosulphuret of potass, &c. be treated with sulphuric acid, the preparation of the Iode, becomes more difficult.

Mr. Mannoury Dectot has invented a new hydraulic machine, a report concerning which has been presented to the French Institute. The principle of this machine is to communicate the whole of the momentum of a body of water entering a vessel, after falling from a height, to a solid body within that vessel, except

so much as may be necessary to carry it off through a hole in the bottom. This object is effected by making the water enter horizontally into a cylindrical trough containing a solid cylinder with a space of 1 1-2 inches between them, near its top, and in the direction of a tangent to the cavity. The water, in passing through the annular space between the cylinders, and thence through a hole in the bottom, communicates a motion to the machine, which, by experiment, has been found from 7-10ths to 75-100ths of the whole calculated force of the falling water, a greater effect than any other machine has ever produced.

Sir H. C. Englefield, Bart F. R. S. has invented a new transit instrument in which the telescope is placed with its axis perpendicular to the plane of the meredian, and the object seen by reflection in a mirror placed at an angle of 45 degrees immediately in front of the object glass. When the telescope is properly placed, any part of the whole semicircle of the meredian may be seen by merely turning it on its axis. The same gentleman has also given a new mode of placing the transit instrument correctly.

The following results have been given to the world by Joseph Read, M. D. of Cork, as deductions from several experiments made by him on the solar ray:

1st. That incident light has never yet been decomposed; and that Sir Isaac Newton, and other philosophers, only decomposed light reflected from opaque substances, or fringes of blue, red, and yellow.

2d. That there are only three primary colours, blue, red and yellow by the mixture of which, either by the prism or painter, all the others are formed.

3d. That Herschel, Leslie, Davy, Englefield, and other philosophers, drew their conclusions relative to the heating power of the prismatic colours from erroneous data, viz. from experiments on reflected light, whose heat must, in a great measure, depend on the reflecting media, and, also, on the thickness and thinness of those parts of the prism through which the fringes pass.

We give his deductions in his own words, and must confess that his experiments and reasoning furnish an apparently plausible objection to the Newtonian theory of the separation of white light into rays of different colours. His second deduction is by no means new. Dr. Woollaston had already proved clearly that there were only three, or, at most, four colours in the spectrum; and Dr. Read appears to have forgotten, or not to have known, his experiments

and those of Herschel's, which showed that the solar beam was divided by the prism (according to Newtonian language) into two other substances beside the coloured rays, one of which was found between the red ray and the direction of the incident rays, and was the matter of heat or caloric. The other, a hitherto unknown substance, which blackened the salts of silver, and appeared to be that part of the solar ray which causes the colours of vegetables, &c. which we know would, if not exposed to it, become white and colourless. These experiments establish the certainty of the Newtonian theory on a ground not to be shaken. Besides, had Dr. Read reasoned correctly on his experiments, he would have found that the circumstance of the light remaining white in the centre of the spectrum, when admitted in large quantities upon the prism, arose from the same cause that misled Newton, viz. as to the number of the prismatic colours, the aperture being larger than was necessary to obtain the coloured rays entirely separate, and in Dr. Wollaston's experiment the aperture was an oblong of the smallest breadth that could admit the light free from inflection. In Sir Isaac Newton's experiment the aperture, a quarter of an inch, was sufficient to blend the colours so as to produce the intermediate shades, and in Dr. Read's the aperture, of four inches, threw the separated rays in confusion on the middle part of the spectrum so as to reproduce white light.

This is not the first time that Sir Isaac Newton's doctrines have been attacked in this point. The celebrated Euler, and many others, have opposed the existence of light as a substance altogether, and have supposed its appearance to arise from the vibrations of an elastic medium. Newton's optics, however, stand on a basis of mathematical demonstration, and their merits will not fall should even his deductions from his prismatic experiments be proved to be founded on false reasoning. R.

Dr. Read some years ago, advanced the production of caloric by the agitation of water in a close tube: which has not been confirmed. T. C.

Distilling.—The method of distilling by steam introduced into the wash, is doubtless the best yet found out. Count Rumford first shewed how several vessels of water might be boiled by the steam conveyed from one boiler common to all of them. He is the inventor of the process. Whether steam be applied to boil water, to boil the liquor in a dyer's copper, or the wash in a dis-

tiller's hogshead, the principle is the same. This is the reason why I did not think myself entitled to a patent for being the first in this country who distilled by steam. In the fall of 1809 I adapted a lid to a boiler in Dr. Priestley's laboratory, and soldered it on. A safety valve was made of an inch tube of copper soldered in the lid. The liquor was supplied by a small wooden cistern above, with a pipe going near to the bottom of the boiler. A tube from the boiler at right angles, conveyed the steam into the vessel containing the wash or beer: the tube reached to within four inches of the bottom of this vessel. It had a cock adapted in it so that the steam could be stopped off at pleasure. M. Schmid, who afterwards conducted Mr. Jos. Priestley's distillery, assisted me. John Hall, Esq. the late marshal of Philadelphia, himself well conversant in the business, and Enoch Smith, Esq. of Sunbury, dining with me one day while this experiment was going on, I shewed them the process itself, as they will testify. I find a patent has been taken out for this method by some one who has just as much title to the invention as any reader of this article. The right of taking out patents is abused so egregiously, that it has become a perfect nuisance. T. C.

Whiskey. In Lancaster county, Pennsylvania, during a year ending with April 1814, six hundred and eleven stills, manufactured 3,295,500 gallons of whiskey.

Iron Works. At Cornwall furnace Mr. Coleman made 3351 tons of pigs and castings from May 3, 1799, to March 21, 1801.

The same gentleman, at Colebrook furnace, from May 8, 1799, to August 8, 1800, made 2033 tons of pigs and castings.

From September 10, 1800, to October 1, 1801, at the same furnace, 1594 tons.

From October 14, 1801, to February 14, 1803, at the same furnace he made 3350 tons.

Roofs of Houses. The danger incurred lately by the cities of Baltimore and Philadelphia from the near approach of the enemy, suggests the propriety, or rather the absolute necessity of exchanging the shingle roofs for some material of a less combustible description. In England houses are covered with plain tiles, or with pan tiles, or with blue slate, or with copper, or with lead. Zinc and tinned iron have also been proposed. I have also seen a kind of plain tile made of thick pasteboard as incombustible as

copper, and when painted and sanded not likely to be affected by moisture. In many foreign countries the roofs are of plaister. There are two objections to metal roofs in this country, the high price and the great heat in summer. They are much the lightest and most durable kind of roof. I am at present of opinion that the paper or pasteboard roofs are the most eligible. They might be painted with tar and sprinkled with sifted sand, washed ashes, or lime. The pasteboard is well sized with glue. They might be tanned soon after being made, by infusing in a solution of oak bark if necessary, but this would not be. T. C.

Provisions. The expence of provisioning troops, the frequent scarcity of provisions on a march, the neglect and frauds of contractors, the discontents of ill fed troops, and the delays thus occasioned, render it of great importance to find some kind of nutritious food easily transported, and not easily spoiled. I recommended lately in the Emporium, vol. 2. p. 462, 463, Indian corn parched and ground, with bacon or pork and portable soup well seasoned. I am glad to find by the papers of this week before me, that Mr. B. Hawkins, Indian agent for the United States, has publicly come forward to propose parched and ground Indian corn. The corn parboiled, then gradually baked until it assume a fine light brown colour and ground, is eaten with a small quantity of sugar. In a national point of view, this is a subject of very great moment, but Mr. Hawkins and I, shall preach in vain. T. C.

WITH the present number, the present series of the Emporium closes, for reasons that my publishers will state in the envelope to this number; which would have been out in due time, had it not been that the printers were serving their country as volunteers.

My collections on bleaching, dying, calico printing, distilling, tanning, pottery, enamelling, glass making, colour making, drug making, &c. will occupy full two volumes. I shall consider in what way they can be best brought before the public, because I think it will be doing service to the manufacturing interest, and to myself to publish them. T. C.

END OF VOL. III—NEW SERIES.

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